DEPARTMENT OF THE INTERIOR
JOHN BARTON PAYNE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

WATER-SUPPLY PAPER 470

GROUND WATER IN THE NORWALK, SUFFIELD, AND GLASTONBURY AREAS CONNECTICUT

BY

HAROLD S. PALMER

Prepared in cooperation with the
CONNECTICUT GEOLOGICAL AND NATURAL HISTORY SURVEY
Herbert E. Gregory, Superintendent

WASHINGTON
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GROUND WATER IN THE NORWALK, SUFFIELD, AND GLASTONBURY AREAS, CONNECTICUT.

By Harold S. Palmer.

INTRODUCTION.

PROBLEMS RELATING TO WATER SUPPLIES IN CONNECTICUT.

The census of 1910 reported the population of Connecticut as 1,114,756. The area of the State is 5,004 square miles. The average density of population is therefore about 220 to the square mile, but the distribution of population is markedly uneven. More than 53 per cent of the inhabitants are gathered into 19 cities, each containing over 10,000. The cities are rapidly increasing in population, but parts of the State—about 24 per cent of the towns—are more sparsely settled to-day than in 1860. To speak broadly, the people of Connecticut are engaged in two occupations—manufacturing and mixed agriculture. Manufacturing is increasing at a rapid rate; agriculture at a slower rate, but with a distinct tendency toward specialization. The fine scenery of parts of the State has led to the development of country estates and shore homes.

As the stage of culture in a region rises it is necessary progressively to improve and increase the water supplies. Wild tribes are satisfied with the waters of springs and streams. Pastoral peoples need somewhat more water. Agricultural regions must have water at points where it may be conveniently used; wells are made, springs are improved, and surface waters diverted to provide water at the points of utilization. In some arid regions extensive works are constructed to supply water for irrigation, as well as for domestic use and for watering stock. Industrial and mercantile communities, in which the population is concentrated in cities, demand a great deal of water, not only for human consumption but also for innumerable technical purposes, such as for washing fabrics, for cooling metals, and for generating steam in boilers.

An annual precipitation of 45 inches gives Connecticut in the aggregate large supplies of both surface and ground water, but the precipitation is sometimes deficient through periods of several weeks or months. Consequently farmers must endure periods of drought,

manufacturers must provide against fluctuating water power, and the inhabitants of congested districts must arrange for adequate public supplies. With increase in population and diversification of interests conflicts have already arisen between water-power users and domestic consumers, as well as between towns, for the right to use a particular stream or area. Demands are also being made by prospective users of the waters for irrigation and drainage. The quality of water acquires new importance with the effort to improve the healthfulness of the State and to reclaim the waters now polluted by factory wastes and sewage. The necessity of obtaining small but unfailing supplies of potable water for the farm and for the village home furnishes an additional problem, for the condition of many private supplies in Connecticut is deplorable.

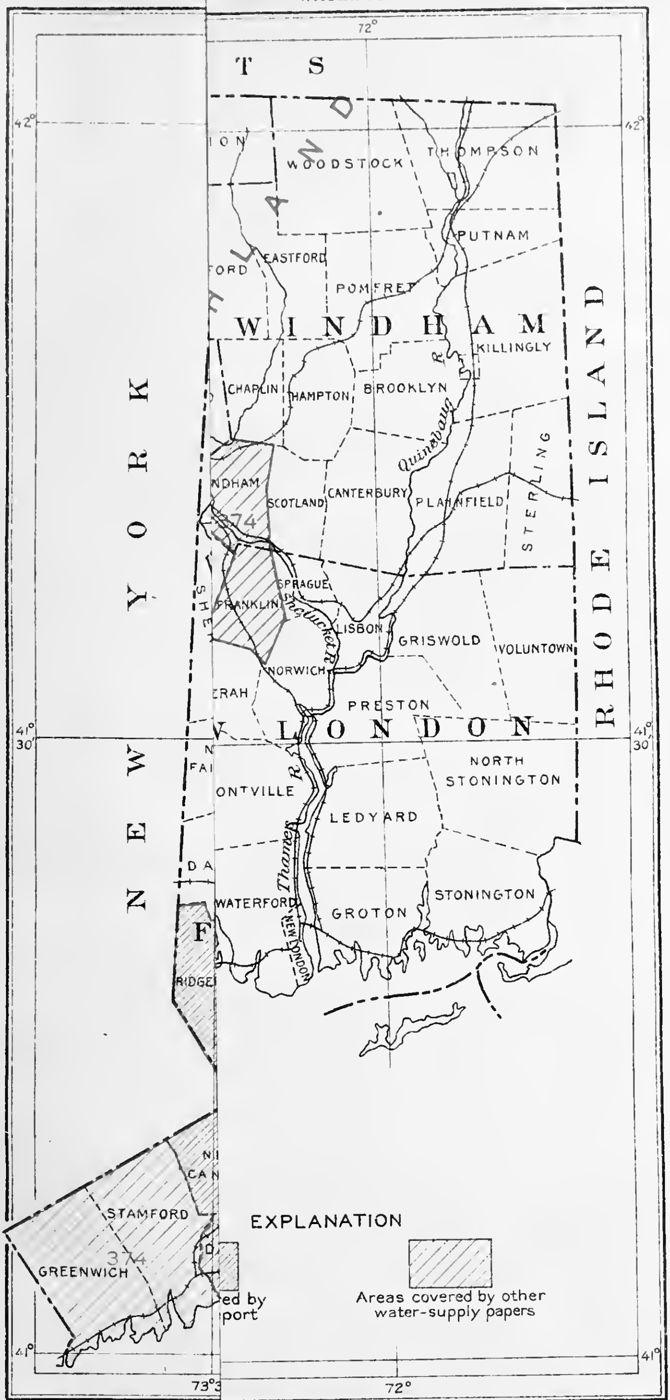
To meet the present situation and to provide for the future, State-wide regulations should be adopted. Obviously the first step in the solution of the Connecticut water problem is to make a comprehensive study of both surface and ground waters to obtain answers to the following questions: How much water is stored in the gravel and sand and bedrock of the State?. How much does the amount fluctuate with the seasons? What is the quality of the water? How may it best be recovered in large and small amounts? What is the expense of procuring it? How much water may the streams of the State be relied upon to furnish? To what extent are the stream waters polluted? How may the pollution be remedied? To what use should each stream be devoted? What is the equitable distribution of ground and surface water among the conflicting claimants—industries and communities?

WATER-SUPPLY INVESTIGATIONS.

The study of the water resources of Connecticut was begun by Herbert E. Gregory in 1903 for the United States Geological Survey. A preliminary report was issued in 1904.[1] A discussion of the fundamental problems relating to the State as a whole, published five years later,[2] meets in a broad way the requirements of the scientist and engineer, but it is not designed to furnish data for use in a quantitative study of ultimate supply and utilization. It was recognized that conditions in the State are so varied that in order to obtain data of direct practical value the conditions in each town and so far as feasible around each farm and each village should be investigated.

[1] Gregory, H. E., [Notes on the wells, springs, and general water resources of] Connecticut: U. S. Geol. Survey Water-Supply Paper 102, pp. 127–168, 1904.

[2] Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, 1909.



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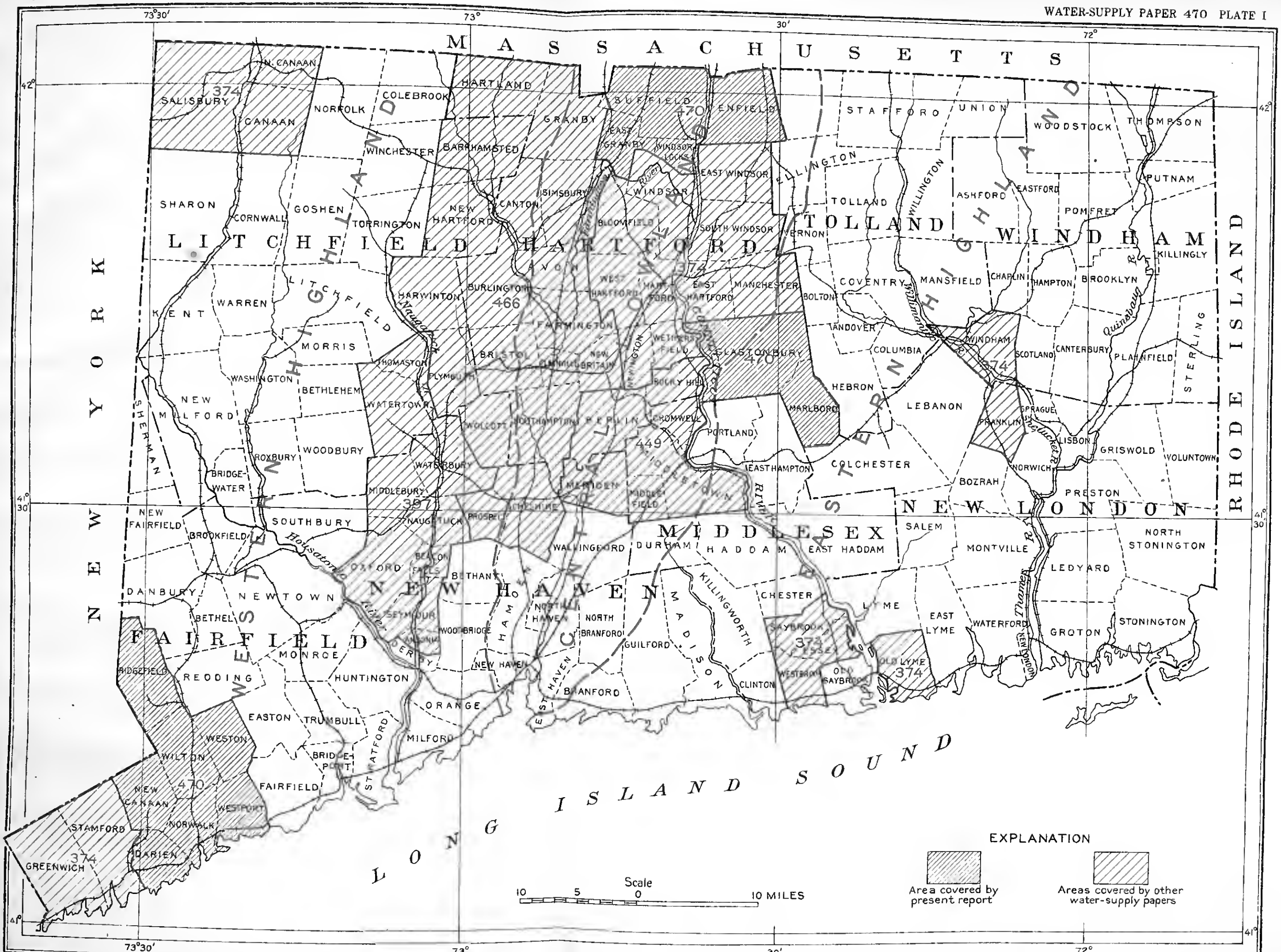

MAP OF CONNECTICUT SHOWING MAIN PHYSIOGRAPHIC DIVISIONS AND AREAS TREATED IN THE PRESENT AND OTHER DETAILED WATER-SUPPLY PAPERS OF THE U. S. GEOLOGICAL SURVEY.

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Realizing the importance of such studies to Connecticut, the State joined with the Federal Government in order to carry on this work, In 1911 a cooperative agreement was entered into by the United States Geological Survey and the Connecticut Geological and Natural History Survey for the purpose of obtaining information concerning the quantity and quality of waters available for municipal and private uses. The investigation was placed in charge of Mr. Gregory and was to be conducted through a period of two years or more, the cost to be shared equally by the parties to the agreement. The work has consisted in gathering information concerning public water supplies: measuring the dug wells used in rural districts, and obtaining other data in regard to them; obtaining data concerning drilled wells, driven wells, and springs; collecting and analyzing samples of water from wells, springs, and brooks; studying the character and relations of bedrock and surficial deposits with reference to their influence upon the ground-water supply.

A. J. Ellis spent the field seasons of 1911, 1912, and 1913 on this work under the cooperative agreement. One report[1] has been published on 13 towns around Waterbury, and another[2] on ten towns around Hartford, four around Saybrook, three around Salisbury, and on Stamford, Greenwich, Windham, and Franklin.

A third report, the field work for which was done by G. A. Waring in 1915, will cover six towns around Meriden and Middletown. A fourth report, the field work for which was done by H. S. Palmer in 1914 and 1915, will cover 18 towns between Southington and Granby. A fifth report on four towns in the Pomperaug Valley is in preparation by A. J. Ellis.

The accompanying index map (Pl. I) shows the areas covered by the several reports. The present report covers three areas—the Norwalk area, comprising the towns of Darien, New Canaan, Norwalk, Ridgefield, Weston, Westport, and Wilton; the Suffield area, comprising the towns of East Granby, Enfield, Suffield, and Windsor Locks; and the Glastonbury area, comprising Glastonbury and Marlboro.

SOURCE AND CHARACTER OF DATA.

The principal well data are given in tables appended to the descriptions of the several towns. The depths of the dug wells were measured with a tape. The information as to depth to rock in wells, consumption of water, and fluctuations and reliableness of supplies

[1] Ellis, A. J., Ground water in the Waterbury area, Conn.: U. S. Geol. Survey Water-Supply Paper 397, 1916.

[2] Gregory, H. E., and Ellis, A. J., Ground water in the Hartford, Stamford, Salisbury, Willimantic, and Saybrook areas, Conn.: U. S. Geol. Survey Water-Supply Paper 374, 1916.

is in general based on statements by well owners. The elevations of wells and springs were taken from the contour maps. The statements as to yield of drilled wells are based on tests made by the drillers when the wells were completed and reported by the owners. Information concerning the flow of a few springs was obtained by measurement of the overflow, the yield of others was computed from measurements of the velocity and cross section of the streams issuing from them, and the yield of still others was estimated by the owners. The kindness of well owners, superintendents of water works, and others in supplying information has been great. The information thus obtained is acknowledged with thanks. Free use has been made of the technical literature dealing with water supplies, and credit is given for specific facts taken from such sources, but the report contains also material gathered from the reports of previous investigations, some of which can not well be attributed to any one author.

GEOGRAPHY.

TOPOGRAPHY.

Connecticut comprises three physiographic divisions, as shown in Plate I—an eastern highland, a western highland, underlain by resistant crystalline rocks, and an intervening central lowland, which is underlain by relatively soft sedimentary rocks.

Norwalk area.—The Norwalk area is in the seaward portion of the western highland. It rises rather gradually northward from sea level at the south, and its highest point is Pine Mountain, in the northern part of Ridgefield, 1,060 feet above the sea. Except near the shore there is very little level ground, and the region comprises ridges and valleys running north and south. The ridge crests approximate in elevation a southward or southeastward sloping plane and mark an old plateau below which the streams have incised their valleys. The general southerly trend of the streams is due to the southerly tilt of the surface.

Suffield area.—The Suffield area is in the central lowland, adjoins Massachusetts, and is crossed by Connecticut River. It is for the most part a nearly level plain, 120 to 280 feet above sea level, above which rise elevations of two types—(1) low, rounded hills with cores of sandstone and cappings of glacial till, and (2) high, long ridges due to the resistance to erosion of upturned sheets of trap rock.

Glastonbury area.—The Glastonbury area is in part in the central lowland and in part in the eastern highland. The lowland portion comprises the northwest quarter of the town of Glastonbury and is a plain similar to the plain of the Suffield area. The highland portion comprises most of Glastonbury and all of Marlboro. It is in general

similar to the Norwalk area in topography, but the trend of the ridges and valleys is less uniform.

CLIMATE.

The outstanding features of the climate of Connecticut are the high humidity, the usual uniformity of precipitation throughout the year, and the relatively great length of the winter.[1] The winters last five or six months, and spring, summer, and autumn are crowded into the remainder of the year. Spring is brief, but summer is longer and well defined and with the exception of short hot waves is very pleasant. The autumn is delightful, as it has many warm days with cool nights. The spring comes so quickly that the snow melts rapidly and sometimes makes strong freshets. The winds are prevailingly westerly, but in May and June there is a good deal of east wind.

The Weather Bureau maintains no stations within the areas here treated, but the data given for New Haven nearly represent the conditions in the Norwalk area, those for Hartford the conditions in the Suffield area, and those for Middletown the conditions in the Glastonbury area. It is probable, however, that in parts of the Norwalk and Glastonbury areas the climate may be a little colder and the rainfall slightly greater because of greater elevation. Some of the more important data for the three stations mentioned are given in the following table:

Climatic data for New Haven, Hartford, and Middletown, Conn.

[From U. S. Weather Bur. Bull. W., section 105, 1912.]

	New Haven.	Hartford.	Middletown.
Temperature (° F.):			
Mean annual	49.5	48.5	48.7
Maximum	101	98	103
Minimum	−14	−20	−15
Precipitation (inches):			
Mean annual	45.89	44.30	49.25
Mean annual snowfall	40.3	47.2	51.7
Frosts:			
First killing (average date)	Oct. 17	Oct. 10	Oct. 2
Last killing (average date)	Apr. 20	Apr. 28	Apr. 27
Earliest recorded	Sept. 28	Sept. 19	Sept. 19
Latest recorded	May 17	May 12	May 12

The precipitation in Connecticut is in general abundant, though sometimes there occur more or less protracted summer droughts. The following tables are summaries of longer tables and show the average, maximum, and minimum monthly precipitation at various points in or near the areas under consideration.

[1] Summaries of climatological data of the United States, by sections: U. S. Dept. Agr. Weather Bureau Bull. W, section 105, 1912.

Summary of monthly precipitation at points in Connecticut.

Norwalk, 1892–1913.[a]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average	3.44	3.60	4.35	3.62	4.09	2.76	3.87	5.10	3.63	4.03	3.56	3.84	45.89
Maximum	6.48	7.08	8.55	7.80	8.53	10.54	10.12	11.38	7.87	9.09	8.86	8.58	57.85
Minimum	1.64	.49	1.22	.77	.07	.56	.83	.37	.98	.68	.95	.92	34.88

Hartford, 1846–1853, 1868–1908.[b]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average	3.47	3.43	4.00	3.14	3.55	3.32	4.30	4.59	3.68	3.85	3.64	3.33	44.30
Maximum	8.48	8.28	9.38	11.17	9.10	10.81	15.14	10.27	10.88	13.33	8.29	9.34	56.36
Minimum	1.08	.50	1.00	.74	.20	.15	1.33	.90	.25	.60	.74	.67	33.64

Middletown, 1858–1902.[b]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Average	4.22	4.33	4.74	3.53	3.88	3.31	4.51	4.85	3.67	4.05	4.26	3.90	49.25
Maximum	9.24	7.56	9.49	13.37	8.05	8.05	13.43	10.22	11.64	14.51	9.50	11.18	68.77
Minimum	1.45	.63	1.12	1.09	.22	.39	1.10	1.16	.49	.89	.75	1.20	37.08

[a] Goodnough, X. H., Rainfall in New England: New England Waterworks Assoc. Jour., Sept., 1915.
[b] U. S. Dept. Agr. Weather Bureau Bull. W, section 105, 1912.

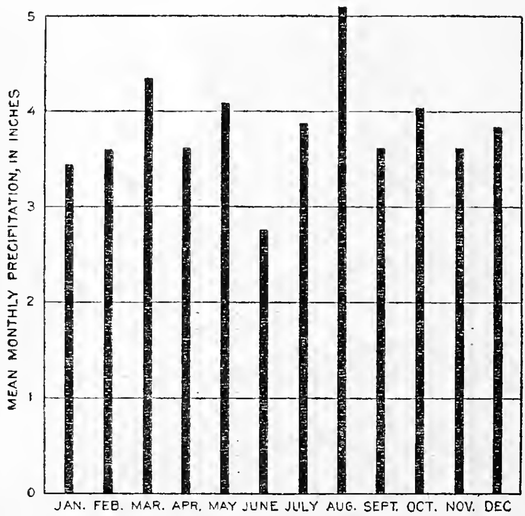

FIGURE 1.—Diagram showing mean monthly precipitation at Norwalk, Conn., 1892–1913.

Figures 1, 2, and 3 are graphic representations of the data given in the above tables.

SURFACE WATERS.

The Norwalk area is drained for the most part by streams 15 to 20 miles long tributary to Long Island Sound, but a little of the

northern part is drained by tributaries of Hudson River. The Suffield area is drained entirely to the Connecticut. The Glaston-

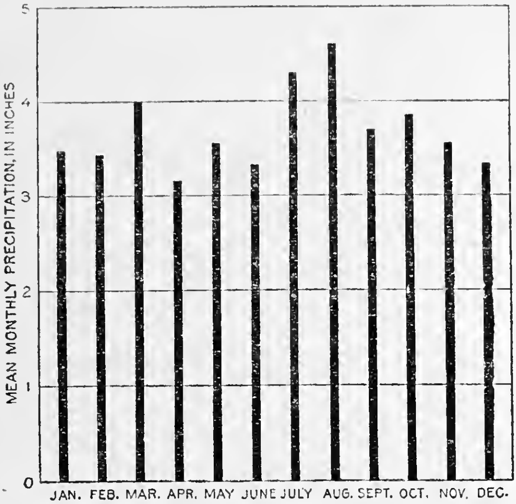

FIGURE 2.—Diagram showing mean monthly precipitation at Hartford, Conn., 1846–1853 and 1868–1908.

bury area is in part drained by westward-flowing streams directly tributary to Connecticut River and in part by southward-flowing

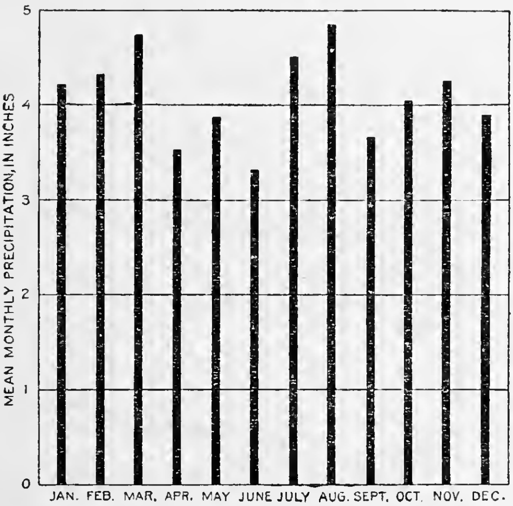

FIGURE 3.—Diagram showing mean monthly precipitation at Middletown, Conn., 1858–1902.

streams that enter Salmon River, which joins the Connecticut at East Haddam. In the Norwalk area and in the highland portion of the Glastonbury area there are many lakes and ponds. Some

of the swamps are former water bodies that have been filled with sediment.

When water falls, as rain or snow, a part evaporates, another part enters the ground, and a part flows off in streams. Some of the ground water eventually returns to the surface in springs, seeps, and swamps and enters the streams. Some is lost by evaporation, and by transpiration of trees and other plants. The ratio of run-off to rainfall varies greatly, as it depends on many factors, including the rate of precipitation, its distribution throughout the year, the character and thickness of the soil, steepness of slopes, abundance of vegetable growth, amount of frost, and character and structure of the rocks.

The following tables give some idea of the amount and variations of the run-off in two basins in Connecticut:

Monthly run-off of Pomperaug River at Bennetts Bridge and precipitation in Pomperaug drainage basin.[a]

[Drainage area 89.3 square miles.]

Month.	Precipitation (inches).	Run-off.	
		Inches on drainage basin.	Per cent of precipitation.
1913.			
August	3.19	0.25	6.8
September	3.53	.35	9.9
October	9.66	2.57	26.6
November	3.05	2.73	89.5
December	2.72	2.24	81.7
1914.			
January	2.15	1.33	61.8
February	2.14	.58	27.1
March	5.63	4.32	76.6
April	4.35	2.94	67.5
May	3.19	2.35	73.6
June	2.83	.63	22.3
July	5.91	.70	11.3
August	3.66	.45	12.3
September	.36	.20	55.6
October	3.31		
November	3.37	.51	14.8
December	2.82		
1915.			
January	6.21		
February	5.70		
March	.15	1.61	1,070.0
April	1.59	1.60	100.6
May	3.37	1.21	35.9
June	2.01	.45	22.4
July	6.31	.78	12.4
August	8.09	1.79	22.1
September	2.94	.92	31.3
Year, October, 1913, to September, 1914	45.65	38.95	85.4
22 months for which the run-off is given	80.20	48.41	60.4

[a] Data obtained from unpublished report by A. J. Ellis, U. S. Geol. Survey.

Precipitation and run-off in Housatonic drainage basin above Gaylordsville, Conn., 1901–1903, and 1906–1909.[a]

[Drainage area, 1,020 square miles.]

Year.	Precipitation (inches).	Run-off. Inches on drainage basin.	Run-off. Per cent of precipitation.
1901	56.91	29.65	52.1
1902	61.43	38.62	62.9
1903	56.85	39.65	69.8
1906	46.31	22.17	47.9
1907	55.80	29.17	52.9
1908	40.26	19.67	48.8
1909	44.75	19.85	44.4

[a] Compiled from Gregory, H. E., and Ellis, E. E., Underground-water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, p. 29, 1909; and from Surface-water supply of the United States, 1907–8 Part 1, and 1909, Part I: U. S. Geol. Survey Water-Supply Papers 241 and 261.

The Tenth Census report on water power gives figures taken from various sources concerning the ratio of run-off to precipitation in a number of drainage basins. The data for four of these basins in the northeastern United States are summarized in the following table:

Precipitation and run-off in certain drainage basins in the northeastern United States.

Basin.	Area of basin (square miles).	Length of record (years).	Annual precipitation (inches).	Average run-off (per cent of precipitation). Mean.	Maximum.	Minimum.
Connecticut River above Hartford	10,234	7	42.7	62.8		
Sudbury River	78	5	46.1	47.6		
West Branch of Croton River	20.37	[a] 4½	50	62.9		
Croton River	339	13	49.79	56.5		

[a] Months.

The difference in the per cent of run-off from the basin of the West Branch of Croton River and from the whole Croton drainage basin is due to the fact that the former is a steep, rocky, thin-soiled, and relatively untilled region, whereas the latter includes much flat-lying and cultivated land and therefore absorbs more of the rain.

WOODLANDS.

The woodlands of the Norwalk area occupy about 38 per cent of the total area and for the most part comprise deciduous tree species. The most prominent trees are oak, hickory, chestnut, elm, maple, beech, and birch, with a few conifers. The woods are more abundant away from the Sound shore. The three shore towns, Darien, Nor-

walk, and Westport, are about 25 per cent wooded, and the four inland towns, New Canaan, Ridgefield, Weston, and Wilton, are about 45 per cent wooded.

The Suffield area is about 38 per cent wooded, and its most cleared portions lie along Connecticut River. Many of the stands on the lowland plains comprise chiefly white and yellow pine and scrub oak, with an undergrowth of sweet fern and "poverty" grass. The flora on the hills is of the deciduous type like that of the Norwalk area.

The Glastonbury area is about 63 per cent wooded and contains chiefly deciduous trees. There are extensive cleared tracts along Connecticut River, but the eastern part of the area is nearly all wooded. The town of Marlboro is about 80 per cent wooded.

In these areas, as throughout other parts of Connecticut, a great amount of cordwood and a good deal of lumber are produced. The manner of cutting has heretofore been very wasteful, and few attempts at reforestation have been made. Cut-over lands have been allowed to grow up with sprout and staddle, and the woodlands have in consequence deteriorated steadily. In the last decade, however, there has been some systematic planting of forest trees, and the cutting has been a little less ruthless. The wood crop would be very profitable were the industry prosecuted in a proper manner, as the soil is in general very good, and if given a chance will mature most kinds of trees sufficiently for the market in 20 or 30 years.

POPULATION.

Population of certain towns in Connecticut.

Town.	Area (square miles).[a]	Population.[b]			
		1900	1910	Per cent gain.	Inhabitants per square mile, 1910.
Norwalk area:					
Darien	12.63	3,116	3,946	27	312
New Canaan	22.86	2,968	3,667	24	160
Norwalk	22.68	19,932	24,211	21	1,068
Ridgefield	35.44	2,626	3,118	19	88
Weston	20.27	840	831	(c)	42
Westport	19.63	4,017	4,259	6	217
Wilton	28.08	1,598	1,706	7	61
Suffield area:					
East Granby	17.72	684	797	17	45
Enfield	34.25	6,699	9,719	45	284
Suffield	43.31	3,521	3,841	9	89
Windsor Locks	8.15	3,062	3,715	21	456
Glastonbury area:					
Glastonbury	54.16	4,260	4,796	13	89
Marlboro	22.97	322	302	(d)	13

[a] Areas measured with planimeter on topographic maps.
[b] Population figures from Connecticut State Register and Manual, 1919.
[c] Loss of 1 per cent.
[d] Loss of 6 per cent.

GEOLOGIC HISTORY.

Very little is known of the early geologic history of Connecticut, for the rocks are very old and have suffered so many changes that the evidence given by them is almost impossible to interpret. It is certain that in pre-Cambrian and early Paleozoic time sediments were deposited. The earliest were sands, muds, and clays, which became consolidated to form sandstone and shale, but later some limestone was deposited. No fossils have been found in these rocks, but they have been referred to the late Cambrian and early Ordovician by studying the relative positions of the formations and by tracing them into regions where more evidence is to be had. Sediments were also deposited during the Carboniferous and very probably in the intervening periods as well.

Toward the end of the Paleozoic era there were several great mountain-building disturbances, characterized by compression of the earth's crust in an east-west direction and the intrusion of vast quantities of igneous rock. To the mashing and intrusion is due the change of the old shales and sandstones to the schist and gneisses of the Norwalk area and the highland portion of the Glastonbury area. The change of the Cambrian and Ordovician limestone to a coarse marble (Stockbridge dolomite) was brought about by the same process. The igneous rocks, in large part, were also crushed and converted to gneisses.

During Triassic time the mountains were deeply eroded and much of the débris was deposited in a troughlike valley in central Connecticut, making the sedimentary rocks of the Suffield area and the lowland portion of the Glastonbury area. These rocks are for the most part red sandstones, shales, and conglomerates, but they include some dark bituminous shales and green and gray limy shales. In some places in the red rocks there are footprints of reptiles, both large and small, and a few of their bones have also been found. The footprints and bones have been identified as belonging to Triassic reptiles. Remains of fishes are found in places in the bituminous shales and further prove the age of these beds to be Triassic.

The deposition of the Triassic sediments was interrupted three times by the gentle eruption of basaltic lava, which spread out across the wide valley floor and which now forms the trap ridges between the Farmington and Connecticut valleys, in part in the Suffield area. Into the buried sediments were also intruded other masses of basaltic lava that formed sills and dikes, such as the sill of Manitick Mountain, in the western part of Suffield. Subsequently (in Jurassic time?) the flat-lying sedimentary rocks and the intercalated trap sheets were broken into blocks by a series of faults that in general

cut diagonally across the lowland in a northeasterly direction. Each block was rotated so that its southeast margin was depressed and its northwest margin elevated.

There is no sedimentary record of the interval between the Triassic period and the glacial epoch, but the erosion that took place then has left its mark. During the Cretaceous period the great block mountains formed by the faulting were almost completely worn away. It is believed by Davis[1] and others that during part of Cretaceous time the sea advanced over Connecticut as far as Hartford, and that the submerged area was covered with marine sediments. No such marine beds have been found, however, and the only evidence of such an incursion of the sea is indirect. Most of the streams in this region flow southward, but parts of the larger ones have southeasterly courses. This condition could be explained by assuming that when the postulated Cretaceous beds were raised they were tilted a little to the southeast and the streams across them took southeastward courses. The more vigorous streams according to this hypothesis were able to cut their southeasterly channels into the discordant rock surface below the Cretaceous deposits, whereas the smaller streams were turned back to the old channels which existed before the Cretaceous sedimentation occurred and which, it is assumed, ran southward.

It was noted by Percival[2] that the highlands may be regarded as "extensive plateaus" which "present, when viewed from an elevated point of their surface, the appearance of a general level, with rolling or undulating outline, over which the view often extends to a very great distance, interrupted only by isolated summits of ridges, usually of small extent." Rice[3] has described the phenomenon as follows:

> If we should imagine a sheet of pasteboard resting upon the summits of the highest elevations of Litchfield County and sloping southeastward in an inclined plane, that imaginary sheet of pasteboard would rest on nearly all the summits of both the eastern and western highlands.

Barrell[4] has shown, however, that the hilltops approximate not an inclined plane but a stairlike succession of nearly horizontal planes, each a few hundred feet lower than the next one to the north. Traces of these terraces are found in many parts of both the eastern and western highlands of Connecticut, but are not discernible in the lowlands. Figure 16 (p. 119) is a composite projection of north-south profiles of hilltops and ridge crests of a part of the Norwalk

[1] Davis, W. M., The Triassic formation of Connecticut: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, p. 165, 1898.

[2] Percival, J. G., Report on the geology of Connecticut, p. 477, 1842.

[3] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 20, 1906.

[4] Barrell, Joseph, Piedmont terraces of the northern Appalachians and their origin: Geol. Soc. America Bull., vol. 24, pp. 688–691, 1913.

area and shows three more or less well-developed planes determined by the concordant elevations.

The rocks of this plateau are the roots of mountains that stood there in late Paleozoic and early Mesozoic time and that were eventually worn away. Erosion produced a more or less smooth inclined plane or series of level planes which when uplifted constituted the plateau surface. Since the uplift erosion has deeply trenched the plateau until only a small part of its original surface is preserved.

During the Pleistocene or glacial epoch the continental ice sheet that overrode most of the northern United States covered the whole of New England. It was of great thickness, and as it moved slowly southward it remodeled the topography by scraping away the decayed rock accumulated at the surface, by breaking off and grinding down projecting ledges of rock, and by redepositing the débris. The major features of the topography were left unchanged, but the details were greatly altered. In general the relief was decreased. The soil mantle was replaced by glacial drift of two types—till and stratified drift. The till, which was deposited directly by the ice, is of moderate thickness, and its surface is similar to the surface of the underlying bedrock but somewhat smoother. The stratified drift, which was deposited by the streams that flowed out from the glacial ice, filled the larger valleys to a considerable extent, making broad plains.

During the recent epoch there has been no considerable change in the topography. Small amounts of alluvium have been deposited in valleys, some swamps have been filled, and some lakes have been changed to swamps by being filled with sediment. There has been slight erosion over the whole region, but the changes are in general imperceptible save for the terracing of stratified-drift deposits in the larger valleys.

WATER-BEARING FORMATIONS.

The water-bearing formations of Connecticut may be divided into two classes—bedrock and glacial drift. The bedrocks are the underlying consolidated, firm rocks, such as schist, granite, trap, and sandstone, and they are exposed at the surface only as small, scattered outcrops. The glacial drift comprises the unconsolidated, loose materials such as sand, clay, and till that occur at the surface in most of the State and overlie the bedrocks. These materials are by far the more important source of ground water and are of two chief varieties—till, also known as "hardpan" or "boulder clay," and stratified drift, also known as "modified drift" or "glacial outwash."

On the geologic maps (Pls. III, V, and VII) are shown the areas occupied by the two principal types of glacial drift as well as the

outcrops of bedrock. The Triassic sandstone (including also shale and conglomerate), the trap rocks, the limestone, and the crystalline rocks are differentiated by color on the maps, but no attempt was made to separate the varieties of the crystalline rocks. The rock outcrops are indicated as small patches, which have roughly the shape of the actual outcrops but most of which are disproportionately large because of the small scale of the map. Inasmuch as in the field work it was necessary to follow the roads, many outcrops in the spaces between roads may have been unmapped.

GLACIAL DRIFT.

TILL.

Till, which is an ice-laid deposit, forms a mantle over the bedrock of much of Connecticut. Its thickness is in general from 10 to 40 feet but in places reaches 80 feet. The average thickness of the till penetrated by 56 drilled wells in the areas under discussion is 24 feet.

The till is composed of a matrix of the pulverized and granulated fragments of the rocks over which the ice sheet passed and of larger pieces of the same rocks embedded in the matrix. The principal minerals are quartz, clay, feldspar, and mica, but small amounts of their decomposition products and of other minerals are also found. There has been but little chemical disintegration and decomposition of the till, and it has in general a blue-gray color. Near the surface, however, where the iron-bearing constituents of the matrix have been weathered, the color is yellow or brown. Where the material is in large part derived from the red Triassic rocks the till has a red-brown to red color. The boulders of the till are characterized by their peculiar subangular shapes with polished and striated facets. Many of the boulders have facets that are in part concave where spalls have been flaked off as the boulders were pressed together in the ice. The boulders are very abundant and are scattered over the fields and in cut banks. As a rule, a number of different varieties of rocks are represented in any one place.

Some of the till, particularly that part below the weathered zone, is very tough, as is indicated by the popular term "hardpan" often applied to it. The toughness is in part due to its having been thoroughly compacted by the great weight of the ice sheets, and in part to the interlocking of the sharp and angular grains. It seems probable that the more soluble constituents of the matrix have to some extent been dissolved by the ground water and have been redeposited in such a way as to cement the particles together.

The relative amounts of the different sizes of material are shown in the following table.[1] The material treated by mechanical analysis

[1] Dorsey, C. W., and Bonsteel, J. A., Soil survey in the Connecticut Valley: U. S. Dept. Agr. Div. Soils Field Operations for 1899, p. 131, 1900.

is the fine earth that remained after the coarse gravel and boulders had been removed. The first three analyses represent till derived in large part from Triassic sandstone and shales; the fourth a till derived from crystalline rocks. The boulders and pebbles mixed with the fine earth (the matrix) constitute from 5 to 50 per cent or even more of the total volume.

Mechanical analyses of stony loams (till soils).

	Diameter in millimeters.	1	2	3	4
Gravel	2-1	2	12.45	5.26	3.05
Coarse sand	1-0.5	3.35	11.86	8.66	3.85
Medium sand	0.5-0.2	8.60	13.98	18.83	8.22
Fine sand	0.25-0.15	31.25	14.78	21.00	11.53
Very fine sand	0.1-0.05	34.22	17.51	18.83	29.82
Silt	0.05-0.01	4.35	8.20	8.70	21.26
Fine silt	0.01-0.005	6.20	8.67	5.30	6.45
Clay	0.005-0.0001	6.57	10.23	10.87	12.20
Loss by drying at 110° C		1.36	1.04	1.01	1.54
Loss on ignition		2.03	1.69	1.77	2.35

1. Stony loam from Triassic rocks half a mile south of Bloomfield, Conn.
2. Stony loam from Triassic rocks, Enfield, Conn.
3. Stony loam from Triassic rocks 1½ miles south of Hazardville, Conn.
4. Stony loam from crystalline rocks 2 miles south of Ashleyville, Mass.

The water-bearing capacity of the till is difficult to estimate for any large area because of its extreme variability. A small sample may be tested by drying it well, then soaking it in water until it is saturated, and finally allowing the excess to drain away. A comparison of the weight after drying with the final weight will show how much water has been absorbed. Gregory [1] made such an experiment on a typical mass of till collected near New Haven, Conn., and determined that 1 cubic foot could absorb about 3.45 quarts of water. In other words, the till is able to absorb water to the extent of 11.55 per cent of its total volume. Other samples would undoubtedly show higher and lower results, but this is probably not far from the average.

The pores of the till are relatively small, so that water does not soak into it very rapidly. On the other hand, the pores are very numerous and are able in the aggregate to hold a good deal of water, as shown above. The fineness of the pores is a disadvantage in that it makes absorption slow, but it is at the same time an advantage in that it retards the loss of water by seepage. The till of Connecticut is more pervious than that of many other glaciated regions, because the hard, resistant rocks from which it was largely derived yielded grains of quartz and other siliceous minerals rather than fine rock flour.

[1] Gregory, H. E., and Ellis, E. E., Underground-water sources of Connecticut; U. S. Geol. Survey Water-Supply Paper 232, p. 139, 1909.

At many places there are lenses or irregular masses of water-washed and stratified material within the unsorted and unstratified till. These were presumably deposited by subglacial streams that existed but a short time before they were diverted or cut off by the forward movement of the ice sheet. The lenses are of considerable value where they happen to be cut by a well, as they in effect increase the area of till tributary to the well and so augment its supply. Well diggers often report that at a certain depth they "struck a spring." Such reports probably refer to cutting into lenses of this type.

The till has no striking topographic expression. The plastering action of the ice sheet by which it was deposited tended to give it a generally smooth surface. In a very few places there are ridges or terrace-shaped masses of till built as lateral moraines along the flanks of tongues of ice that protruded beyond the front of the main ice sheet. In many places the till was heaped up beneath the ice sheet to form drumlins, much as sand bars are built in river channels. The drumlins are gently rounded hills and may or may not have cores of solid rock.

STRATIFIED DRIFT.

In contrast with the till, which was formed by direct ice action, is the stratified drift, a water-laid deposit. Stratified drift may have originated either within, on, under, or in front of the ice sheet. In Connecticut only subglacial and extraglacial stratified drift are found, and except for their topographic expression these two types are very similar.

Stratified drift is composed of the washed and well-sorted, reworked constituents of the till together with some débris made by the weathering and erosion of bedrock. The water that did the work was for the most part the melted ice from the glacier. Since glacial time the streams have in places added to the deposits of stratified drift, but elsewhere and probably to a greater extent they have eroded and removed parts of those deposits. The distinction between the glacial stratified drift and the more recent stream alluvium is hard to draw, and although the latter is a little less clean and yields a little less water, the distinction need not be drawn for a ground-water study. The mapping and separation of mappable units within the glacial drift in this report is based in large part on the capacity of the material for carrying water. A different basis of mapping might be used in a report made for some other purpose.

Near the end of the glacial epoch the climate became mild and vast amounts of ice were melted. The relatively soft till was

easily eroded and supplied a great abundance of débris. Some of the streams flowed in sinuous subglacial channels, in which they made deposits that have now become the long, winding ridges called eskers. The water in some of the channels beneath the ice was under hydraulic head, as is shown by the fact that some eskers cross ridges and gullies regardless of the grades.

Where the débris-laden waters came to the edge of the ice sheet kames were made. Some of the material was carried beyond the front of the ice sheet and was laid down as an alluvial deposit in the valleys. Not all the materials composing the wide outwash plains have been deposited by running water. There are also beds of finer material—clay and silt rather than sand—that were laid down in lakes and ponds which stood in shallow depressions in front of the ice.

The stratified drift consists of lenses and beds laid one against another in a very intricate and irregular way. Some of the lenses consist of fine sand, others of coarse sand, others of gravel, and still others of cobbles, but the sands are the most abundant. The material of each lens is rather uniform in size, but there may be a great difference between adjacent lenses. In general the finer materials form more extensive beds than the coarser. Some of the beds of clay and fine silt, though only an inch or two thick, have a horizontal extent of hundreds of feet. Lenses of gravel may be 2 or 3 feet thick and not extend over 10 feet horizontally.

The sand lenses are composed almost entirely of quartz grains. In the gravel lenses are pebbles of many kinds of rocks. The clay beds consist of true clay, thin flakes of mica, and minute particles of quartz and feldspar. All the deposits contain iron, which gives them brown colors.

The following analyses[1] show the character of the stratified drift:

Mechanical analyses of stratified drift.

	Diameter in millimeters.	1	2	3	4	5
Gravel	2–1	4.98	2.20	0.50	0.00	0.06
Coarse sand	1–0.5	11.31	7.51	1.51	Trace.	.29
Medium sand	0.5–0.25	33.41	33.50	7.96	.21	.40
Fine sand	0.25–0.1	33.75	32.05	23.27	1.50	.73
Very fine sand	0.1–0.05	10.82	13.50	41.82	19.55	5
Silt	0.05–0.01	2.09	4.47	9.15	33.67	32.57
Fine silt	0.01–0.005	1.03	1.75	6.32	28.54	29.10
Clay	0.005–0.0001	1.65	2.78	4.40	9.50	25.65
Loss on drying at 100° C		.50	.80	1.92	2.60	2.17
Loss on ignition		.80	1.30	3.68	4.75	3.53

1. Coarse, sharp sand 2 miles south of Bloomfield.
2. Sandy loam southwest of Windsor.
3. Fine sandy loam half a mile northeast of South Windsor.
4. Recent flood-plain deposits three-fourths of a mile southeast of Hartford.
5. Brick clay from glacial lake beds, Suffield.

[1] Dorsey, C. W., and Bonsteel, J. A., op. cit.

The most striking difference shown by a comparison of this table with the table of mechanical analyses of till samples (p. 21) is that in each sample of stratified drift almost all the material is included within two or three sizes, whereas in the till there is a wider diversity of sizes, even exclusive of the boulders, which were taken out before analysis.

The topographic form assumed by most of the stratified drift is that of a sand plain, which may be modified by terraces, by valleys cut below it, or by kettle holes. In the highlands small bodies of stratified drift form eskers—long, winding ridges, 10 to 40 feet high, in some places with narrow crests and in others with flat tops, and generally with steep flanks. In the lowlands there are kame areas, which consist of hummocky hillocks and short ridges of stratified drift irregularly scattered.

CRITERIA FOR DIFFERENTIATION OF TILL AND STRATIFIED DRIFT.

In many places it is difficult to determine whether the mantle rock is till or stratified drift, and a decision is reached only after weighing several factors. The presence of distinct stratification is indubitable evidence that the deposit is stratified drift, but in localities where there are no outcrops or where the outcrops do not show distinct stratification the determination may be uncertain. Till areas are in general characterized by the presence of numerous large boulders, which in many places have been used for building stone fences. These boulders are subangular and faceted and may have concave surfaces and glacial scratches, which would distinguish them from the well-rounded boulders found in a few places in very coarse beds of stratified drift. Moreover, areas of stratified drift have characteristic topographic features, such as broad plains and terraces, with kettle holes, eskers, and kames. Because of its great porosity the upper part of the stratified drift in many places is dry much of the time and therefore favors certain types of vegetation which either get along with little water or are able to send their roots down very deep. Under such conditions there are likely to be many white and yellow pines, cedars, and scrub oaks, with an undergrowth of sweet fern and poverty grass. The till has no distinctive floral characteristics.

OCCURRENCE AND CIRCULATION OF GROUND WATER.

Some of the water that falls as rain or melts from snow soaks into the ground. A surface layer of sand or gravel or a thick mat of leaf mold or of needles, as in woods, probably affords the most favorable conditions for high absorption. On steep slopes the rain runs off

rapidly and relatively little enters the ground. When the ground is frozen it becomes almost impervious, and absorption is at a minimum. Heavy rains concentrated in a short time will in general result in less absorption than an equal amount of rain over a longer time.

The amount of water that may be absorbed is very great. With a rainfall of 48 inches a year, each acre would receive in the course of a year over 1,300,000 gallons. If one-fourth of this quantity were to soak into the ground and be concentrated into a single spring, that spring would discharge an average of over 2 quarts a minute throughout the year.

Water moves through the ground for the most part because of gravity. The water sinks through the pores of the soil until it reaches an impervious bed or the ground-water level, and then it moves laterally. Except in the stratified drift lateral movement over great distances does not occur in Connecticut, because the porous soils are cut into small discontinuous areas by the numerous ledges of bedrock. In large valleys occupied by stratified drift there is in general an underflow in the direction of the surface streams. Inasmuch as the porous soil cover over the bedrock is as a rule not very thick, the direction of movement is for the most part the same as the slope of the surface of the ground. The rate at which water moves depends on the amount of water, the steepness of the slopes, and the porosity and permeability of the water-bearing materials. Porosity is the ratio of the volume of the crevices between the grains to the total volume of the substance, and does not depend on the size of the pores. Permeability is the capacity of the material to transmit water and depends largely on the size of the individual pores. Large crevices like those of gravels favor rapid circulation. Some fine clays have as high porosity as the gravels, but because of the interstitial friction in the minute pores they are virtually impermeable.

At some depth the pores of the earth are saturated with water. The rains and melting snows supply water which would saturate the rock deposits throughout but for the lateral escape of the ground water. The upper surface of this saturated zone is known as the water table.

In Connecticut the water table is in general near the surface of the ground in and after seasons of high precipitation in areas where the mantle rock is thin or discontinuous and where the surface is relatively level. High, level terraces are an exception to this rule. The water table is likely to be particularly high in small deposits that fill depressions in the surface of the bedrock. Along the edges of streams, lakes, and swamps the water level is at the surface. It is relatively low in times of drought on steep slopes and in places

where the mantle rock is thick. The depth to the water table fluctuates with the seasons and may be increased by drainage of wet grounds, by heavy draft on wells, and by transpiration from vegetation, as well as by changes in the rates of precipitation and evaporation. The improvements made by man on farms and the engineering works in cities artificially lower the water table. In Connecticut the greatest fluctuation is on steep hillside slopes from which the water drains rather readily. In such situations there is also rapid though often temporary replenishment of the ground water after rains.

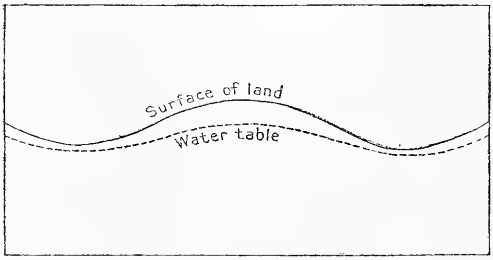

FIGURE 4.—Diagram showing the usual relation of the water table to the land surface on hills and in valleys.

There are in Connecticut no extensive water-bearing formations such as the Dakota sandstone, which is used as a source of water supply in much of the Great Plains. The ground waters in Connecticut are derived from rain or melting snow near by. In many places water lies at the base of the mantle rock, where rapid downward movement is prevented by the relatively impervious bedrock. Many wells dug to solid rock and blasted a few feet into it take advantage of this supply. This water bed also feeds water into the fissures of the bedrocks.

The till and stratified drift contrast greatly in texture and therefore in their ability to hold up the water table. Because of its greater permeability the stratified drift not only absorbs water more readily than the till but also loses it more readily. In most regions the water table is nearer the ground surface in valleys than on hills, as shown in figure 4. In much of Connecticut, however, where the valleys are filled with stratified drift and the hills are covered with till, the reverse condition exists. Because of the much slower rate at which the water percolates through the till the water table is held up nearer the surface on the till-covered hills than in the valleys of stratified drift, as is diagrammatically shown in figure 5.

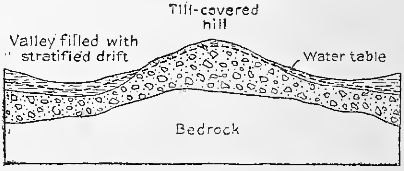

FIGURE 5.—Diagram showing the relation of the water table on till-covered hills to the water table in valleys of stratified drift in glaciated regions.

With respect to their capacity for yielding water there is also a very important difference between the two types of glacial drift. On account of its high porosity and permeability, the stratified drift in

many places contains large quantities of water which it will yield freely to wells and which may be readily replenished when rains come. The till, on the other hand, contains much less available water and gives it out at a much slower rate. (See p. 21.) The stratified drift is the more valuable for obtaining large supplies from wells for municipal and industrial uses, but the till is likewise of great value, as it is widely distributed and in general yields enough water for domestic use to inexpensive dug wells. The till is also the reservoir which feeds most of the small springs that make gravity supplies for many farms.

TRIASSIC SEDIMENTARY ROCKS.

DISTRIBUTION.

The mantle rock of the Suffield area is underlain by rocks of Triassic age. Most of these are sedimentary, but the ridge of Peak Mountain, in East Granby and Suffield, is in part underlain by trap rocks. The northwest corner of the town of Glastonbury, in the Glastonbury area, comprising about 18 square miles, is underlain by Triassic sedimentary rocks. No rocks of this age occur in the Norwalk area.

LITHOLOGY AND STRATIGRAPHY.

The lowest of the Triassic beds lie unconformably on the upturned edges of the crystalline rocks and may be seen in contact with these rocks at a few points along the western border of the area they underlie. The boundary against the crystalline rocks on the east is believed to be a major fault.

According to Rice and Gregory,[1] the Triassic sediments

> would naturally be characterized in a broad way as red sandstone. The sandstones, sometimes coarse, sometimes fine, consist mainly of grains of quartz, feldspar, and mica resulting from the disintegration of the older rocks which form the walls of the trough in which the sandstones were deposited. The prevailing red colors of the sandstone are not due to the constituent grains, but to the cementing material, which contains a large amount of ferric oxide. * * * While the name sandstone would properly express the prevalent and typical character of the rock, the material is in some strata so coarse as to deserve the name of conglomerate and in others so fine as to deserve the name of shale. In the conglomerates the pebbles may be less than an inch in diameter, but they are sometimes much coarser. In some localities occurs a rock which has been called "giant conglomerate," in which some of the boulders are several feet in diameter. The conglomerates occur chiefly near the borders of the Triassic areas, and in these it is especially easy to recognize the rocks from the disintegration of which the pebbles have been derived. In general, it may be said that the pebbles in any particular area are derived

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[1] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, pp. 163–165, 1906.

from rocks in the immediate vicinity. The conglomerates in the Connecticut Valley area are obviously derived from the gneisses, schists, and pegmatites, which are the prevalent rocks of the highlands. * * * The shales, like the sandstones and conglomerates, are prevailingly red, owing their color likewise to the presence of ferric oxide. Some strata of shale, however, contain in considerable quantity hydrocarbon compounds derived from the decomposition of organic matter. These bituminous shales are accordingly nearly black. In the Connecticut Valley area there are two thin strata of these bituminous shales, which have been shown, by careful search for outcrops, to have a very wide extent. The red sediments, however, are dominant. There is great variation in the material composing the beds and in their structure, and the changes in the rock are very abrupt. The stratification is uneven and irregular, and the beds are wedge-shaped or lenslike rather than uniformly thick over wide extents.

Although the beds were originally horizontal and in continuous masses they have been tilted to the east 15° or 20° and have been broken into blocks. The forces which caused the faulting also opened many joints and fissures, along which there has been little or no movement. These joints are in general parallel to the bedding or nearly at right angles to it, though joints are found with every conceivable inclination. The sandstones and conglomerates have more abundant and more extensive joints than the shales, for they are rigid and relatively brittle rather than plastic and tenacious. The joints are rarely more than 50 feet apart and in general are found at intervals of 2 to 8 feet. The joints are more abundant and wider near the surface than they are in depth.

OCCURRENCE OF GROUND WATER.

Ground water occurs in the Triassic sedimentary rocks in four ways—in pores throughout the rocks, along bedding planes, in joints, and along fault zones. Though originally derived from rain and snow the water has, for the most part, reached the Triassic beds by infiltration and percolation from the saturated mantle rock.

Water in pores.—The sandstone, shale, and conglomerate consist of particles of quartz, feldspar, mica, and other less abundant minerals and of pebbles of older rocks, all cemented together by fine clay and films of iron oxide. The spaces between the grains are not completely filled with the cementing material but are partly open and may contain water. In the aggregate large quantities of water are held in this way, but on account of the smallness of the openings the water is not readily given off. Bare outcrops, as in quarries, are for the most part dry on the surface, though the interior of the rock may be moist. In the sandstones and conglomerates the water in the pores is slowly given off to joints, from which it may be recovered by means of drilled wells. The shales have pores so very fine that they yield but little water. In some places the shales are so impervious as to act as restraining beds that concentrate the water in the pores of the coarser beds.

Water in bedding planes.—There is a tendency for the water in the pores to be concentrated in and transmitted along the lower

parts of the coarser beds where they rest on finer and relatively impervious beds. It is probable that a few of the wells drilled in Triassic rocks draw their supplies from such horizons.

Water in joints.—Joints are the most important source of water in the bedrock of Connecticut. They are more abundant and are wider in the sandstone and conglomerate than in the shale. These extensive flat crevices are good water bearers because they are large and offer little capillary resistance to the circulation of water, because they draw on and make available the supply of water stored in pores, and because they are of relatively great extent. Most of the drilled wells and a few dug wells in the Triassic areas draw on the joints.

Water in fault zones.—The faults that break the Triassic rocks of Connecticut into great fault blocks are not single fractures but rather zones containing many parallel planes along which movement has taken place. Because of the great number of water-bearing joints in such zones wells drilled along fault lines are likely to yield very large supplies of water.

TRAP ROCKS.

DISTRIBUTION.

Trap rocks underlie parts of Peak Mountain, in Suffield and East Granby, and of Manitick Mountain, in Suffield. There is also a small dike in the eastern part of the town of Westport, in the Norwalk area. Their extent is so small that they are not an important source of water.

LITHOLOGY AND OCCURRENCE OF GROUND WATER.

The trap rocks are dense, heavy dark-gray to nearly black rocks and are more or less completely crystalline on a small scale. Like the sedimentary rocks in which they are inclosed, the traps are cut by numerous joints, some of which were made by the initial cooling and shrinkage of the rock and others by the jarring incidental to faulting and tilting. The joints are more abundant near the margins of the masses.

Trap rocks have a twofold bearing on the occurrence of ground water. The joints may contain water and the sheets may act as impervious layers to restrain the circulation. Trap rocks have a very low porosity and carry virtually no water in pores, and they contain no water corresponding to that along bedding planes of sedimentary rocks. Water circulates through the joints and fault zones in traps just as in sandstones, but in general less abundantly. Evidence of such circulation is given by the yellow and brown stains of iron along

the joints, due to oxidation and hydration of the iron-bearing minerals. The immediate source of the water in the trap rock is the water in the formations with which it is in contact; this water enters it through the network of interconnecting joints. Because of its hardness and resistance to erosion the trap forms bold hills with cliffs. This is a disadvantageous form so far as water storage is concerned, because of the facility with which water will drain out.

CRYSTALLINE ROCKS.

DISTRIBUTION.

Crystalline rocks, so named because their constituent mineral particles consist of crystals rather than fragments, underlie all of the Norwalk area except about 9 square miles in Ridgefield, in which the bedrock is limestone, and all of the Glastonbury area except the sandstone area in the northwestern part of the town of Glastonbury. The extent of these rocks is about the same as that of the eastern and western highlands, because the characteristic typographic features of the highlands depend in large part on the resistance of these rocks to erosion.

LITHOLOGY.

The areas under consideration contain three types of crystalline rocks—schists, gneisses of igneous origin, and gneisses of complex origin.

Schists.—Typical schists are metamorphosed sandstones and shales, which in turn are consolidated sands and muds. The mountain-making movements to which this region has been subjected squeezed and folded the sedimentary rocks. At the same time the great changes in temperature and pressure metamorphosed the rocks completely; the quartz sand grains were crushed and strung out, and the clayey material was changed to crystalline mica. The mica flakes were turned roughly parallel to one another and so give the rock a pronounced cleavage, called schistosity. Though other minerals are present the quartz and mica are dominant. In the Norwalk area the Berkshire schist is of this type, and in the Glastonbury area the Bolton schist.

Gneisses of igneous origin.—In connection with the dynamic metamorphism of the region great masses of molten rock were intruded into the sedimentary beds. They have been metamorphosed like the schists but to a lesser degree, and the changes are textural rather than mineralogic. The dark minerals of the igneous rock have been somewhat segregated and parallelly oriented, so that the rock

has a fair cleavage. The Thomaston granite gneiss[1] and the Danbury granodiorite gneiss[1] of the Norwalk area and the Glastonbury[1] and Maromas granite gneisses of the Glastonbury area are of this type.

Gneisses of complex origin.—The intrusions of igneous material were in part massive and gave rise to the gneisses of igneous origin, as described above, and they were in part in the form of multitudinous thin injections into the schists. Certain parts of the schist have been so extensively injected that their character is materially altered, and they have become gneisses of complex origin. The thin intrusions for the most part follow the planes of schistose cleavage and somewhat obscure them, but others cut across them. The Waterbury gneiss[1] of the Norwalk area and the Hebron gneiss[1] of the Glastonbury area are of this type.

OCCURRENCE AND CIRCULATION OF GROUND WATER.

Water in lamellar spaces.—In the schists and to some extent in the gneisses of complex origin, but not in the granite gneisses, there is a little water in the spaces between the mica flakes where they are bent around quartz grains. Most of the openings are flat, thin, and not extensive, and they interconnect very imperfectly. In the most thoroughly crumpled schists there are small tubular openings along the furrows and ridges. The schistose structure aids in promoting the circulation of ground water chiefly because it gives rise to numerous joints.

Water in joints and along faults.—The forces that caused metamorphism also made many fractures in the rocks. The fractures are even more numerous in these rocks than in the sandstones, but they bear water in the same way. Inasmuch as it is virtually impossible to trace faults in the crystalline rocks they will be considered here only as compound or enlarged joints in which circulation is especially vigorous.

There are two principal sets of joints, one of which is nearly horizontal and the other nearly vertical. The vertical joints, according to Ellis,[2] are from 3 to 7 feet apart where jointing is well developed. In some sheeted zones 1 to 15 feet wide the joints are spaced at intervals of 3 inches to 2 feet, but in some places they are 100 feet

[1] Some of the geologic names used in this report (Thomaston granite gneiss, Danbury granodiorite gneiss, Glastonbury granite gneiss, Waterbury gneiss, and Hebron gneiss) are the provisional names given to the rocks on the preliminary geologic map of Connecticut by Gregory and Robinson (Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907). These names are herein used only for reference and may differ from those which will finally be adopted by the United States Geological Survey in its geologic folios.

[2] Gregory, H. E., and Ellis, E. E., Underground-water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, p. 65, 1909.

apart. Though the spacing increases with increasing depth it is on the average less than 10 feet to a depth of 100 feet. Ellis finds that the horizontal joints are on the average 1 foot apart for the first 20 feet, between 4 and 7 feet apart for the next 30 feet, and from 6 to 30 feet apart at depths of 50 to 100 feet. The intersecting horizontal and vertical joints form a very complicated system of connecting channels through which water may circulate. Water is supplied to the network of channels by percolation from the overlying mantle of soil, and it may be recovered by means of drilled wells.

LIMESTONE.

DISTRIBUTION.

The Stockbridge dolomite underlies about 9 square miles of valley land in the town of Ridgefield, in the Norwalk area.

LITHOLOGY AND STRATIGRAPHY.

The Stockbridge dolomite is a metamorphosed dolomitic limestone, composed chiefly of calcite and dolomite, and for the most part has a thoroughly crystalline texture. Some zones, however, have been but slightly metamorphosed and have still the texture of a typical limestone. Because of the solubility of the calcite the rock has slight resistance to erosion and constitutes valley areas. It is one of the few formations in Connecticut whose age is definitely known, for it has been traced into regions in Massachusetts where fossils have been found.

OCCURRENCE OF GROUND WATER.

Water is carried in the Stockbridge dolomite in the same way as in the schists, gneisses, and sandstones, namely, in joints. The joints, however, have been in large part widened by the solvent action of the water flowing through them, so that they are excellent channels of circulation and should yield abundant supplies of water. It is to be expected, however, that the waters derived from this formation will be rather hard. Unlike most dolomitic marbles Stockbridge dolomite has a very low porosity and carries but little water in pores.

ARTESIAN CONDITIONS.

The word "artesian" is derived from the name of the old French province of Artois, in which wells of this type first became widely known. Originally the term was applied only to wells from which water actually flowed, but now it is applied to wells in which the water rises by hydrostatic pressure above the point at which it

enters the hole. The term is sometimes improperly used for any deep well of small diameter, regardless of whether the water is under pressure or not. The question whether an artesian well will flow or not depends as much on the altitude of the mouth of the well as it does on the pressure of the water.

The essential conditions for artesian waters are the existence of a bed of porous or fractured rock through which water may flow, having an elevated outcrop where water may soak into it, with relatively impervious strata above and below to prevent escape of water and loss of pressure, and a supply of water to the outcrop sufficient to fill the reservoir.

In Connecticut these conditions may be fulfilled in two principal ways—where sandstones between shales or sandstones between trap sheets function as the pervious and impervious strata, or where a blanket of compact till forms the restraining layer over bedrock that is pervious by reason of a network of fissures. In general, the rocks

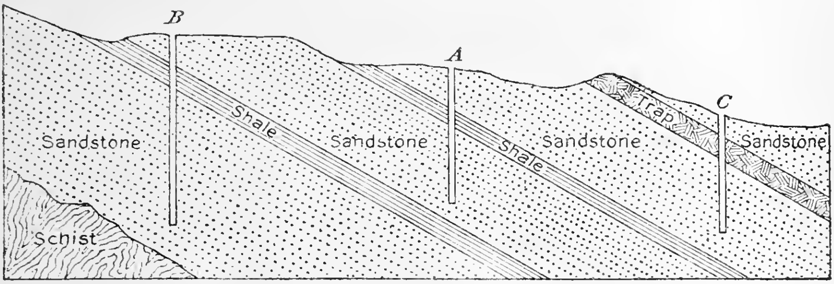

FIGURE 6.—Diagram showing conditions under which artesian waters may exist in the Triassic sedimentary rocks in Connecticut.

contain so many faults and open joints that the water escapes and its pressure is dissipated, so that flowing wells are few. Nearly all the wells are artesian, however, for the water in them rises considerably above the point of entrance.

A few wells pass through beds of relatively impervious shale and draw water from porous sandstone, as shown in figure 6. The underlying restraining member may be either a shale bed, as at A, or the dense crystalline mass on which the Triassic beds rest, as at B. In general the beds of the Triassic sedimentary rocks are not of sufficient lateral extent to form important reservoirs. In a few wells a sheet of trap rock forms the upper restraining member, as illustrated at C in figure 6.

The wells that draw water from the network of fissures are much more numerous than those drawing from the pores of the sandstones and conglomerates. In some of these rocks there are no connecting joints that might discharge water below the level of the wells; in

others the joints are tight enough to offer material resistance to the escape of water. Other wells draw water from fissured rock that is overlain by an impervious blanket of till that acts as a restraining member.

SPRINGS.

A spring, in the broadest sense of the word, is a more or less definite surface outlet for the ground water. Springs are formed where the surface of the ground is so low that it reaches the water table. A well is in a sense an artificial spring, for it is made by artificially depressing the ground surface so that it reaches the water table. The springs in the areas covered by this report may be grouped under three principal heads, as described below.

SEEPAGE SPRINGS.

One method of escape of water from the ground is by slow seepage in saturated areas on hillsides and along swamps and streams. This process may go on over a wide space if the formation is of uniform texture, or it may be concentrated in a small body of more porous material. To the latter class belong the so-called "boiling springs," in which the water enters with sufficient force to keep the sand bottom in gentle motion. In a spring of either class the supply may be artificially concentrated by the excavation of a collecting reservoir.

Seepage springs are very likely to be found in small swales cut back into a slope. It seems probable that the flow of water is the primary cause of the excavation of the swales, but that the swales secondarily tend to concentrate the flow. Areas of diffused seepage may develop into true springs by such a process.

STRATUM SPRINGS.

Stratum springs are those in which an outcropping or only slightly buried ledge or layer of impervious material interrupts the flow of ground water and forces it to the surface. Springs of this type may be made by a ledge of rock underlying saturated soil, by beds of sedimentary rock of different porosity, or by a body of till underlying stratified drift.

FAULT AND JOINT SPRINGS.

Faults and joints greatly facilitate the circulation of water through rocks, and where they reach the surface they may supply springs. Some faults carry a good deal of water under considerable pressure and are in a sense analogous to artesian wells.

RELATIONS OF WELLS TO SPRINGS.

Wells may be considered artificial springs. (See above.) Some springs that have been improved by excavation to a considerable depth are hard to distinguish from wells that have obtained water

at moderate depths. In this report the criterion taken for classifying such springs is the original condition of the ground. If it appears to have been a wet or springy spot, the term "spring" is applied regardless of the depth of excavation. If the surface was dry in the first place, the term "well" is applied no matter how shallow the depth at which the water table was found.

RECOVERY OF GROUND WATER.

DUG WELLS.

CONSTRUCTION.

Dug wells are constructed by digging holes in the ground deep enough to extend below the water table. The excavation is generally made 8 or 10 feet in diameter, and in it is built a lining of dry or mortared masonry or brickwork, concrete, vitrified tile, or planking. As the well is walled up the space outside the lining is filled. The filling should be of some porous material, such as gravel, in order to facilitate percolation into the well, but many well diggers pay little attention to this matter. Most dug wells when completed are 3 to 5 feet in diameter, though some are much larger, and their depth may be as much as 50 feet or more. The average depth of the 707 dug wells tabulated in this report is 18.3 feet, and they contain on an average about 5 feet of water.

LIFTING DEVICES.

A number of different devices are in use for raising water from dug wells. All are types or modifications of a simple bucket for bailing out water, the displacement pump, the impeller pump, or the siphon.

Bailing devices.—The most primitive method of lifting water is by bailing with a dipper in shallow wells or with a bucket hung from a rope in deeper wells. In some places the rope is replaced by a light pole with a snap ring at the end by which the bucket is held. These devices are not only inconvenient and laborious to use but are unsanitary. The "one-bucket rig" comprises in addition to the rope and bucket a gallows-like frame from which is hung a pulley to carry the bucket rope. The "two-bucket rig" is similar except that it has a bucket at each end of the rope, thus eliminating the necessity of sending down the bucket before drawing water.

In the "sweep rig" the bucket is hung by a rope or slender pole from the small end of a sweep 15 to 40 feet long. The sweep is pivoted at a crotch in a convenient tree or over a pole set firmly in the ground and has at its butt a counterbalance weight.

In the "wheel and axle rig" the rope from the bucket winds around a wheel 2 to 4 feet in diameter with a grooved face to keep the rope from slipping off. The wheel is carried on an axle 4 to 8 inches in diameter suspended above the well. Wound around the axle is a second rope to which a heavy stone or block of iron is hung. The greater weight of the stone acting on the axle counterbalances the lesser weight of the bucket acting on the large wheel.

In the "windlass rig" the rope from the bucket winds around a drum 5 or 6 inches in diameter to which a crank is attached. The windlass is set over the well, and on the drum are flanges to keep the rope from running off. Many are provided with a ratchet to prevent the bucket from falling back and with a brake to use in lowering the bucket. In some the rope is replaced by a chain either of the ordinary sort or of flat links, by leather straps, or by flat straps of mild brass.

The "counterbalance rig" is a modification of the windlass rig in which the rope instead of winding around a drum passes over a pulley carried on the crank axle. One end of the rope has a bucket and the other a weight that more than counterbalances the empty bucket but is lighter than the full bucket. In some rigs a chain and suitably notched pulley are used instead of a rope and smooth pulley.

The rigs described above, as they are generally installed, are open to objection on sanitary grounds. At far too many wells the open curbs and inward-sloping surrounding surface allow access of foreign matter to the water, and moreover there is danger of pollution from the handling of the bucket and rope. All the devices are much safer when the curbs are tight and hinged covers are provided which may be closed except while water is actually being drawn. It is also advisable to bank up earth around the well curb or to build a concrete apron around it so that surface water and drippings will flow away. With some of the rigs it is possible to avoid transfer of filth from the hands by using an automatic filling and dumping bucket, an ordinary bucket equipped with a pair of metal prongs opposite each other on the rim. For a few feet next to the bucket the rope is replaced by a flat chain which, as it rolls onto the drum, turns the bucket so that one or the other of the metal prongs engages a cross rod inside the curb. By further winding the bucket is tipped and emptied into a spout. With this arrangement it is unnecessary either to handle the bucket or to open the curb, which may, therefore, be made tight against foreign matter.

Pumps.—Among the principal classes of pumps are displacement pumps, bucket pumps, impeller pumps, and air lifts. Displacement pumps are of two principal sorts—pitcher pumps and deep-well

pumps. Both consist of a cylinder in which a piston moves. At the bottom of the cylinder and in the piston are valves that open upward. When the piston is raised by means of the handle and connecting rod, water rushes into the cylinder from below, and when the piston is depressed the water rises through its valves. Repetition of the movement raises the water in successive small masses. In a pitcher pump the working cylinder is at the top of the pipe, above the ground, and the part of the pump above the piston is shaped to a spout. In a deep-well pump the working cylinder is at some depth and is connected with the delivery pipe by a closed cap. On top of the delivery pipe is a standard to carry the pump handle, from which a long rod runs down through the delivery pipe to the piston. Some deep-well pumps are double acting—that is, they have extra valves so arranged that water is raised on both

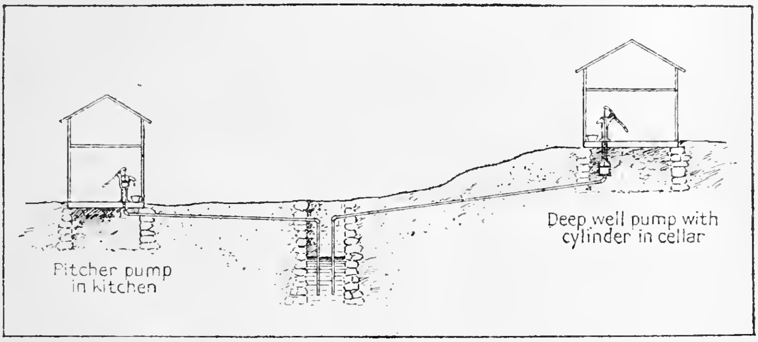

FIGURE 7.—Diagram showing two types of installation of "house pumps."

the rising and the descending piston stroke instead of only on the rising stroke. Deep-well pumps are superior to pitcher pumps in that they are less liable to freezing, need little or no priming, and can be used in deeper wells by lowering the working cylinder.

A displacement pump may be installed in the house or barn at some distance from the well, as shown in figure 7. The suction lift (vertical distance between cylinder and water level) should not be more than 20 to 25 feet for moderate horizontal distances and still less if the pump is far from the well. In this report installations of this kind are called "house pumps." Some have a pitcher pump on the first floor and others have a deep-well pump with the working cylinder in the cellar and the pump-handle standard on the first or even the second floor.

Chain pumps are used in many wells in Connecticut and are of two types—rubber-bucket pumps and metal-bucket pumps. A rubber-bucket pump is a displacement pump of special type and consists of a long tube through which is passed an endless chain that has thick rubber washers on special links at intervals of 6 to 10 feet. At the

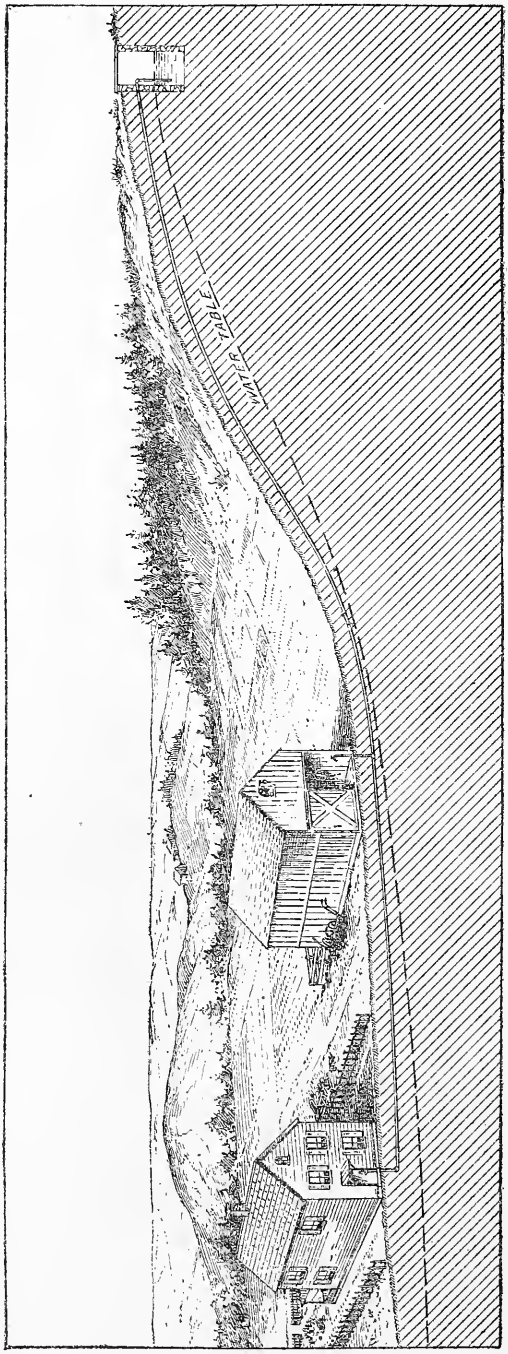

FIGURE 8.—Diagram showing siphon well and domestic waterworks.

top the tube is fastened to a curbing, across the top of which is an axle with crank and sprocket wheel to take the chain. When the crank is turned the chain is drawn up through the tube and the rubbers act as pistons and raise water which is discharged through an opening in the tube near the top.

A metal-bucket pump, though similar in external appearance, is quite different in principle. A chain, made of alternating plain flat links and special flat links that are fitted with small metal buckets, passes over a sprocket wheel turned by a crank. The buckets are about 2 inches square and 4 inches deep, and each has a lip so constructed that as it passes over the wheel it empties the water it has carried up from below into a hopper connected to a spout.

All these pumps are sanitary if the curbing and platform are tight enough to prevent waste water, surface drainage, and solid foreign matter from entering the well.

In a few places where garden truck is raised the high value of the crops, especially if forced for early markets, makes the pumping of

water for irrigation profitable. Wells of large diameter are dug, but as the sanitary quality of the water is unimportant they need not be covered nor very carefully walled up. Where the water table is high and the yield of the well large, as in parts of the plains underlain by stratified drift, centrifugal pumps driven by gasoline engines have been found satisfactory. Inside a closed casing is a fanlike wheel, which is rotated at high speed and gives the water enough centrifugal inertia to force it out through a tangential discharge pipe. A partial vacuum is produced at the center of the pump, and water rushes in through a central side opening. These pumps have to be primed, but they are little troubled by grit in the water. If properly designed and of the right size for the task assigned them they are very efficient.

Siphon and gravity rigs.—Dug wells situated higher than the points at which the water is to be used may be developed by means of siphon pipe line provided the water level is not more than 25 feet below the ground and is above the point of delivery. Figure 8 illustrates such an installation. In some wells, where the water level is near the surface and where no hill intervenes between the well and the point of delivery, and in many springs a direct gravity system may be used, obviating the necessity of occasionally priming the siphon. The gravity and siphon rigs are sanitary provided the surroundings of the well or spring are clean. If the pipe is of lead care should be taken not to use any water that has stood a long time in the pipe. In some places where the fall from the well is not enough to carry the water to the first floor of the house the water is allowed to run continuously into a cistern or tank in the cellar, from which it is pumped by hand. The overflow of siphon and gravity systems is in many places used to supply watering troughs.

Rams.—Springs of large yield which lie lower than the point of utilization may be developed by means of hydraulic rams. A few exceptional wells also may be developed in this way. The hydraulic ram is a mechanical device which uses the momentum of a relatively large volume of water falling a short distance to raise a small volume of water to a relatively great height. Theoretically 100 gallons falling 10 feet would have enough energy to raise 10 gallons 100 feet or 1 gallon 1,000 feet, and other quantities and heights in proportion. However, on account of leakage through the valves and elasticity and friction in the pipes this condition is not realized. According to tables given by Björling,[1] when the ratio of lift to fall is 4 to 1 the ram will lift 86 per cent of the theoretical amount; with a ratio of 10 to 1, 53 per cent; and with a ratio of 25 to 1, only 2 per cent. Björling says further that the length of the drive pipe (from spring to ram) should be 5 to 10 times as great as the fall. The delivery

[1] Björling, P. R., Water or hydraulic motors, pp. 261–271, 1894.

pipe (from the ram to the storage tank) should have an area of cross section equal to one-fourth or one-third that of the supply or drive pipe (from the spring or well to the ram). The rapidity of the beat should be as great as is compatible with perfect and complete action of the valves and in most rams may be regulated by adjusting springs or weights on the main valve. The noise made by rams is considerable and is transmitted along iron pipes but may be reduced by the use of lead pipe or of a section of rubber hose.

Many people have been disappointed in trying to use rams because they did not realize their limitations. Rams must of necessity waste a large portion of the water. Before installing a ram careful measurements should be made of the flow of the well or spring during its lowest season, the amount of fall available, the amount of lift desired, and the horizontal distance from well to ram. If these data are supplied to the makers they will be able to recommend the best model and size of ram. With proper conditions a suitable ram correctly installed will furnish a reliable, inexpensive, and permanent supply. It is customary to have the ram deliver the water to a tank or reservoir in an elevated position from which it is distributed by gravity.

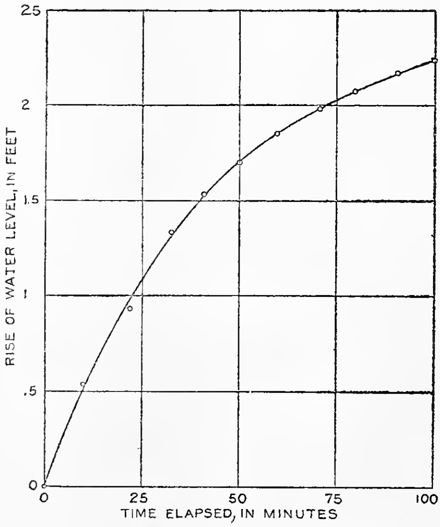

FIGURE 9.—Graph showing the recovery of the well of J. S. Dewey after pumping.

Windmills and air-pressure tanks.—A popular method of supplying water is by the use of a windmill, pumping jack, pump, and reservoir. Another equipment used by many people is the air-pressure system. A pump driven by a gasoline engine or electric motor pumps water into a closed steel tank containing air. As the water comes in it compresses the air and gives pressure sufficient to drive the water through the piping in the house. The pump is fitted with a snifting valve, which takes in a little air with each stroke to replace that dissolved by the water. Some of the tanks are equipped with telltales which give a signal or automatically start the motor when the water level in the tank is reduced below a set point It is the usual practice to put the tank in the cellar, but some are in specially constructed pits outside.

Tanks and reservoirs built in the open are apt to allow the water to become disagreeably warm in summer and to give trouble by freez-

ing in winter. The heating in summer is an advantage in irrigation, as the warm water gives less shock to the plants on which it is put.

YIELDS OF DUG WELLS.

One of the most important questions relative to the recovery of ground water is the amount available. A study was made of the dug well of Mr. J. S. Dewey (No. 3. Pl. IV) near Granby station in East Granby. The well was dug in stratified drift to a depth of 24 feet, is 4 feet in diameter, and rarely has more than 5 feet of water. At the time the well was visited it had been pumped continuously for five hours. Mr. Dewey very kindly stopped pumping in order that the recovery of the well might be observed. At intervals of about 10 minutes measurements were made of the depth from a datum point on the curb to the water surface. The results are given in the following table:

Rise of level in J. S. Dewey's well.

Time elapsed.	Length of interval.	Depth to water surface from datum.	Total rise of water surface.	Rise during interval.
Minutes.	*Minutes.*	*Feet.*	*Feet.*	*Feet.*
0	0	26.47	0	0
10	10	25.95	.52	.52
22	12	25.53	.94	.42
33	11	25.14	1.33	.39
41	8	24.94	1.53	.20
50	9	24.77	1.70	.17
60	10	24.62	1.85	.15
71	11	24.49	1.98	.13
80	9	24.40	2.07	.09
91	11	24.30	2.17	.10
100	9	24.23	2.24	.07

These data are also graphically expressed in figure 9. As the well has a diameter of 4 feet, the area of the cross section is 12.6 square feet, and a rise of 0.01 foot is equivalent to an inflow of 0.126 cubic foot, or 0.94 gallon. The rate of inflow in any interval may be expressed by the equation

$$I=\frac{R\times 0.94}{t}$$

where I=rate of inflow in gallons per minute, R=the rise of water level in hundredths of a foot, and t=the length of the interval in minutes.

If the curve in figure 9 is extended upward and to the right, it will become asymptotic to a horizontal line representing a total rise of about 2.5 feet. It is reasonable to assume that when pumping was stopped the water had been depressed about 2.5 feet below its original level. Then the original level must have been 2.5 feet above the 26.47-foot level, or about 24 feet below the datum. The drawdown

of the water level at any moment may be obtained by subtracting 24 feet from the distance from the datum to the water level at that moment, as was done for the first column of the following table. The second column gives the total inflow in gallons for each of the 10 intervals ($=R\times0.94$), and the third column gives the rates of inflow as obtained by the formula above. In the fourth column is given the mean drawdown for each interval, found by averaging the drawdown at the start with the drawdown at the end. In the fifth column are given the ratios of the rate of inflow to the rate of drawdown. The average of these is 2.11, which means that reducing the level in the well by 1 foot increases the rate of inflow by 2.11 gallons a minute. The values in the third and fourth columns are plotted against one another in figure 10. The rather uniform slope of the line joining these points is expressive of the relative uniformity of the values found in the fifth column.

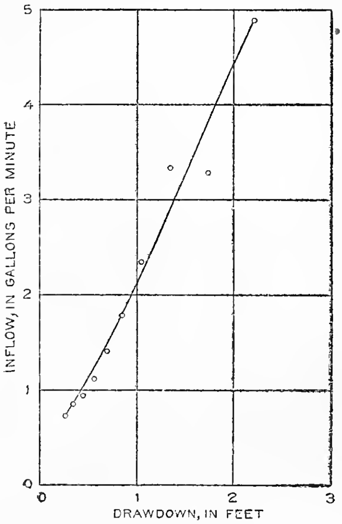

FIGURE 10.—Graph showing the relation of inflow to drawdown in the well of J. S. Dewey.

Relation of rate of inflow to drawdown.

Drawdown.	Total inflow for interval.	Rate of inflow for interval.	Mean drawdown for interval.	Inflow in gallons per minute for each foot of drawdown.
Feet.	*Gallons.*	*Gallons per minute.*	*Feet.*	
2.47	0			
1.95	48.80	4.88	2.21	2.21
1.53	39.48	3.29	1.74	1.89
1.14	36.66	3.33	1.34	2.49
.94	18.80	2.35	1.04	2.26
.77	15.98	1.78	.86	2.07
.62	14.10	1.41	.70	2.01
.49	12.22	1.11	.56	1.98
.40	8.46	.94	.45	2.09
.30	9.40	.85	.35	2.43
.23	6.58	.73	.27	2.70
				[a]2.21

[a] Average.

By operating this pump so as to keep the water level down about 1.75 feet below the level it holds normally when not being pumped an inflow of about 3.5 gallons a minute is obtained. This well could be made to yield at least 210 gallons an hour or about 5,000 gallons a day.

Similar tests made on a well dug in till indicate a capacity of only 320 gallons a day, and other tests on a well blasted into Triassic sandstone and drawing its water from fissures in the rock showed a capacity of 216 gallons a day.[1]

INFILTRATION GALLERIES.

An infiltration gallery is a modification of a dug well and derives its water in the same way. Turneaure and Russell[2] say of them:

> Where ground water can be reached at moderate depths it is sometimes intercepted by galleries constructed across the line of flow. * * * In form a gallery may consist of an open ditch which leads the water away, or it may be a closed conduit of masonry, wood, iron, or vitrified clay pipe, provided with numerous small openings to allow the entrance of water. * * * Galleries are usually constructed in an open trench. They are generally arranged to lead the water to the pump well, and may be provided with gates so that the water may be shut off from various sections. The cost of galleries is about the same as that of sewers in similar ground. It rapidly increases with depth, but up to 20 or 25 feet it is sufficiently low so that the construction of galleries can often be advantageously undertaken. A gallery not only intercepts the water more completely than wells, but it replaces the suction pipe, it is more durable than either pipe or wells, and all trouble from pumping air is avoided.

Filter galleries may be so constructed that surface water is flooded over the ground around and above them and is collected in them after percolating through the soil. This will remove most of the suspended matter that makes the raw water unsightly, but unless frequent bacteriologic examinations are made it should not be trusted to completely eliminate the germs of disease. Chlorination or similar treatment might well be added as part of the process.

DRIVEN WELLS.

Driven wells are made by driving pipes into the ground with a maul or machine resembling a pile driver. The pipe is made up of enough sections to reach the ground-water level, and may have either an open end or a closed end.

In closed-end driven wells a drive point slightly larger than the pipe is used to penetrate the ground. Above the point is a perforated section through which the water enters. As the pipe is driven down sections are screwed on to lengthen it. The pipes are in general from three-fourths of an inch to 3 inches in diameter, and the screens from 2 to 4 feet long.

Open-end driven wells are made by driving a plain pipe which may or may not have a heavy cutting shoe attached to it. The material inside the pipe is removed by means of a sand pump or

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[1] Palmer, H. S., Ground water of the Southington-Granby area, Conn.: U. S. Geol. Survey Water-Supply Paper 466 (in press).

[2] Turneaure, F. E., and Russell, H. L., Public water supplies, pp. 318–320, 1909.

water jet. In the jetting method water is forced down a small pipe inside the drive pipe, and as it rises it carries up the sand, silt, and smaller pebbles. The pipe is perforated either before driving or by special tools operated from the inside after driving. In the East rather small pipes are used, but in the West a special casing 10 or 12 inches in diameter made of sheet metal is often provided.

Several kinds of pumps are used with driven wells. With domestic driven wells of small bore the usual practice is to screw a pitcher pump to the top of the pipe. In some of the larger driven wells a deep-well pump is put down inside the drivepipe, and in others a specially constructed section of the drivepipe acts as the cylinder. A centrifugal pump is used in some of the western driven wells of very large size and heavy yield.

Driven wells are suited to loose sands and gravels in which caving would make trouble in digging wells. They are inexpensive and have the advantage that if they are unsuccessful the pipe may be withdrawn and used again in another place. One disadvantage of the smaller ones is the proneness of the screen to become clogged by an incrustation of mineral matter or by silt, and another is that grit may be drawn up with the water and score the working parts of the pump so that it works poorly. Wells of the large type are the best adapted for obtaining large supplies from the stratified drift or other sandy or gravelly deposits. They should be more largely used instead of the small types of driven wells where large supplies are required. Driven wells are not suited to till because the presence of boulders makes driving difficult or impossible and because the yield of the till is insufficient for a satisfactory supply.

DRILLED WELLS.

Drilled wells are in general deeper than dug or driven wells and in general obtain their water from cracks or fissures in bedrock. They are made either by a percussion machine (churn drill) or by an abrasion machine (core drill). A percussion drill has a long steel bar with a hardened and sharpened bit at the lower end which is worked up and down by an engine and pounds its way through the rock. At intervals the drill is withdrawn for sharpening and the débris is removed by means of a sand pump. Abrasion machines are built to revolve a hollow steel cylinder shod with diamonds or with chilled steel shot, which cut a circular channel surrounding a core. At intervals the drill is removed and the core broken into sections and extracted. The portion of the hole above bedrock is cased with steel or wrought-iron pipe, which should be driven into the bedrock and firmly set to prevent the entrance of surface water. Drilled wells in Connecticut range from 4 to 12 inches in diameter, but most of

them are 6 inches in diameter. The average depth of the 129 drilled wells tabulated in this report is 213 feet.

Where only moderate amounts of water are needed a pump of the deep-well type operated by hand or by power is hung in the well. In some wells where large amounts of water are to be raised from a great depth use is made of an "air lift." Compressed air is forced down an air pipe and delivered near the bottom of a discharge pipe, and then expands and rises, bringing water with it. The delivery pipe may be hung inside the well with the air pipe alongside it (*a*, fig. 11), or the rock wall and casing may act as the delivery pipe (*b*, fig. 11). It is essential that the length of the submerged portion of the air pipe should be from 30 to 70 per cent of the distance from the bottom of the air pipe to the point of discharge. In shallower wells the percentage of submergence must be greater than in deeper wells. The pressure used ranges from 20 to 100 pounds to the square inch and is often calculated at one-fifth to one-quarter of a pound for each foot of lift. The two great advantages of the air lift are that it has no moving parts in the well where they would be inaccessible in case of wear by grit in the water, and that it may be controlled and operated from a distant air-compressing station. The efficiency, however, is not very high in many installations.

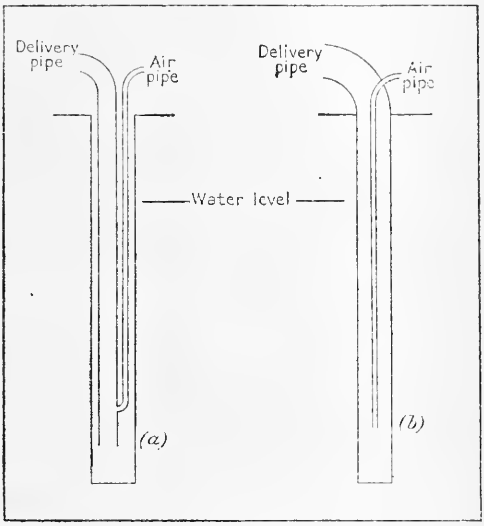

FIGURE 11.—Diagram showing two types of air lifts.

The success or failure of drilled wells can not be predicted because of the irregular distribution of the water-bearing fissures, but the statistical studies of Gregory and Ellis show that drilling at any point will probably procure a satisfactory supply. Among the 237 wells drilled in crystalline rocks in Connecticut studied by Ellis,[1] only 3 wells, or 1.24 per cent, are recorded as obtaining no water. A supply of 2 gallons a minute is considered abundant for domestic needs, though insufficient for industrial purposes. Among the 134 wells drilled in crystalline rock whose yield Ellis ascertained "only

[1] Gregory, H. E., and Ellis, E. E., Underground-water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 323, p. 91, 1909.

17, about 12.5 per cent, furnish less than 2 gallons a minute." It is probably a conservative estimate to state that not less than 90 per cent of the wells sunk in the crystalline rocks have given supplies sufficient for the use required. Wells may be unsuccessful not only as regards quantity but also as regards the quality of the supply. Along the shore in the Norwalk area are many drilled wells that have brackish water, which enters through fissures that open also to the salt water of the Sound. (See p. 69.)

Although wells are reported by Ellis that obtain water at all depths from 15 to 800 feet, the largest percentage of failures is in wells over 400 feet deep. This is due to the less number of joints and their greater tightness in depth. From a consideration of the greater cost per foot of drilling and of the lesser probabilities of success it is concluded that if a well has penetrated 250 feet of rock without success the best policy is to abandon it and sink in another locality.

Gregory,[1] in writing of the wells drilled in sandstone, says that "of the 194 wells recorded, only 11, or 5.6 per cent, failed to obtain 2 gallons a minute, the minimum amount desired for domestic purposes." The average yield of 112 of these wells is "$27\frac{1}{2}$ gallons a minute. the largest being 350 gallons and the smallest two-thirds gallon." As with wells drilled in crystalline rocks, so with wells in sandstone, it is considered "good practice to abandon a well that has not obtained satisfactory supplies at 250 to 300 feet."

SPRINGS.

In developing a spring as a source of water supply it is advisable to make some sort of a substantial collecting basin. No materials which may rot should be used. Rotting works in two ways to injure a water supply; it adds objectionable decayed organic matter and it weakens the walls and allows the entrance of surface water which may be polluted. No spring should be so arranged that water is dipped from it, as this process may readily transfer pollution from the hands. The reservoir should be covered and a pipe provided to carry off the flow, as this method not only prevents pollution from the hands, but also prevents contamination by animals around the spring. If a spring is used for watering stock a pipe and trough should be provided.

In order that the water may enter readily the reservoir should be thoroughly perforated or should be open at the bottom, but it should have stout, water-tight walls extending a foot or two above and below the surface to prevent entrance of surface wash. Where it is desired to use the full flow of the spring, the shape of the springy

[1] Op. cit., p. 130.

area determines the shape of the reservoir, which will allow of nearly complete recovery. If only a moderate supply is needed the reservoir may be of any convenient shape. Small springs may be developed by setting a length of large pipe of concrete, iron, or vitrified tile vertically in the ground. Such tile is superior to the wooden cask or box used at many springs because of its greater durability and lesser expense in the long run. Whatever the type of the reservoir it should be provided with a cover or roof that will effectually keep out leaves, sticks, wind-blown dirt, and small animals.

GROUND WATER FOR PUBLIC SUPPLY.

INTRODUCTION.

The use of ground water for public supplies is a comparatively recent development in New England. Though most of the people a century ago used ground water, which was obtained on a small scale from dug wells and springs, the growing need for large supplies was met in most places by surface water. Since 1880, however, a number of waterworks which use ground water have been constructed in New England, and doubtless more will be built in the future.

The chief advantages of a properly constructed and properly located ground-water supply over a surface supply are uniformly low and agreeable temperature, sanitary safety, and absence of disagreeable odor, color, or taste. The chief disadvantages are that the water may be more highly mineralized, the amount available may be inadequate, and the cost of construction and operation may be greater. The choice of a source of supply, the method of development, and adequate provision for extension of the system with increased consumption are matters in which communities should procure expert advice.

Most ground-water systems for public supply comprise one or more batteries of driven wells connected by suction mains to pumping plants which discharge into small reservoirs with distributing pipes. A few plants use dug wells or infiltration galleries. The driven wells are similar to those described on pages 543–544, except that they are in general of greater diameter than domestic wells. They are so located that they will draw from as great an area as possible with the least amount of piping, but with consideration for the difference in the abundance of the supply throughout the field. If the direction of the underflow is known, the lines of wells are placed across it in order that the maximum yield may be intercepted without interference among the wells.

In selecting sites for wells it is essential to consider the character of the water-bearing formation. As a rule, only small supplies can be obtained from the till or from the underlying bedrock, but large supplies, such as are required for public waterworks, can be developed in many places from the extensive deposits of sand and gravel that constitute the stratified drift. These deposits and the surface features by which they can be recognized are elsewhere described. (See pp. 22–24.) The distribution of the stratified drift in the towns discussed in this report is shown on the maps (Pls. III, IV, and VI).

A number of test wells should be sunk and should be vigorously pumped in order to determine the water-bearing capacity of the formation at different points and depths. The pumping should be as heavy and as long continued as possible, in order that any deterioration in the quality or abundance of the water may be detected and so that as strong yields as possible may be developed. Analyses of samples collected at intervals and measurements of the yield should be made. The static level in open wells near the test wells should be observed before, during, and after pumping to ascertain the amount and extent of the drawdown of the water table and its rate of recovery.

In order to get successful wells with large yields in the stratified drift, it is necessary to clean the wells out thoroughly and thus to get rid of the fine sand and to develop around the intake of the well a reservoir of clean gravel. The wells should be not less than 8 inches in diameter and should have casings extensively perforated with circular holes one-fourth inch or more in diameter or slits not less than one-fourth inch wide. The wells should be pumped vigorously for a long time, preferably with an air lift, but if an air lift is not available, by means of a centrifugal pump, in order to get out the sand. It is desirable in developing a well to pump it at its maximum capacity or at least considerably harder than it will be pumped when it is put into service. If this is done there will generally be not much trouble with sand when the wells are in use and are pumped at the more moderate rate.

The methods of developing wells in incoherent and poorly assorted sand and gravel deposits, such as the stratified drift, are much better understood in the western part of the United States, where hundreds of thousands of acres are being irrigated with water pumped from such wells, than in the East, where there has in general been less need for large underground supplies. If the methods described above, which are extensively used with success in the West, were applied to the stratified drift, wells yielding several hundred

gallons a minute could no doubt be obtained in many places. If waterworks can be supplied by one well of large yield or even by a few such wells the cost of maintaining the wells and the cost of pumping will be less than where there is a large battery of small wells having casings with small perforations or screens of fine mesh which generally become partly clogged and do not admit water freely.

The source of the water may be rainfall on the adjacent region or underflow from some body of water, or in part from both. Water from a surface body is greatly improved in quality by passing slowly through a mass of soil. Water derived chiefly from absorption of rainfall by the soil has a temperature of 48° to 52° F., which is the general temperature of the earth below the depth of diurnal variation. Surface waters are much warmer in summer and colder in winter, so that a wide range of temperature in the driven-well water would indicate surface origin.

The experience at many plants at which ground water is pumped into open reservoirs is that there is likely to be a heavy growth of algae, even more than where surface waters are thus stored. Roofing the reservoirs is found to reduce or eliminate the algal growths, for they thrive only in abundant light. Roofed reservoirs also keep the temperature more uniform. As roofing is expensive, however, the usual practice is to have much smaller storage capacity and to depend on the pumps to keep pace with the fluctuations in consumption.

An excessive amount of carbon dioxide, iron, or manganese in some supplies has been troublesome. Carbon dioxide has made a good deal of trouble at the plant at Lowell, Mass., and experiments were made in 1914 to find a remedy.[1] It was found that spraying the water under low pressure from small nozzles would aerate it and thus eliminate the gas. By another set of experiments, conducted at the same time, for the removal of iron and manganese which had increased in amount as the draft on the supply increased, the conclusion was reached that "the iron and manganese can be successfully and economically removed by limited aeration, passage through a coke prefilter not less than 8 feet in depth, operated as a contact bed at a rate of 76,500,000 gallons per acre daily, and subsequent filtration through sand at a rate of a million gallons per acre daily." The rate of filtration and the details of construction of the filter beds would be somewhat different with waters of different content of carbon dioxide, iron, and manganese.

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[1] Barbour, F. H., Improvement of the water supply of the city of Lowell, a special report to the municipal council, 1914.

TYPICAL PLANTS.

GREENFIELD, MASS.

At Greenfield, Mass., ground-water supply supplements the surface supply.[1] Near Green River a well 40 feet in diameter and 30 feet deep was made by sinking a cylindrical concrete caisson. The water level is only 5 feet below the surface, and the earth is loose and pervious. Pieces of 2½-inch pipe were placed in the concrete walls during construction in order to permit ready entrance of water. The well is covered by a domed concrete roof. At one time 2,000,000 gallons of water were pumped daily for about two weeks, though the pumps are generally run only part time and draw only about 1,200,000 gallons daily.

HYDE PARK, MASS.

The Hyde Park Water Co. formerly had a ground-water supply. The supply was drawn from 150 driven wells connected to a central collecting chamber, and the water was pumped through the mains to a reservoir and standpipe with a combined storage capacity of 2,000,000 gallons. The pumps had a capacity of 2,500,000 gallons a day, and there were 32.4 miles of mains, 1,806 service taps, and 178 fire hydrants.[2] The original equipment, installed in 1885, comprised 64 driven wells 2 inches in diameter, from 25 to 38 feet deep.[3] The wells were pumped in 1886 at the rate of 1,000,000 gallons a day for seven days. The water level was depressed from 8 to 15 feet below the surface—that is, it was lowered 7 feet—but recovered overnight. The pumps were unable to lower the level below 15 feet.

LOWELL, MASS.

Lowell's first waterworks, built in 1870, comprised a filter gallery 1,300 feet long parallel to and 100 feet distant from Merrimack River, from which water was pumped to a distributing reservoir. The supply was about 900,000 gallons a day (1875), and as the daily consumption became greater a supplementary supply was pumped direct from the river and passed through a sand filter. Epidemics of typhoid fever in 1890 and 1891 necessitated a better supply. Test wells were driven at different places near the city, and finally a contract was awarded to the Cook Well Co. for a 5,000,000-gallon supply to be obtained by driven wells along River Meadow Brook. Forty-five 6-inch wells of the open-end type, 47 to 67 feet deep, were

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[1] Merrill, G. F., The Greenfield waterworks: New England Waterworks Assoc. Jour., June, 1915, pp. 149–159.

[2] Baker, W. N., Manual of American waterworks, 1897.

[3] Discussion, in New England Waterworks Assoc. Jour., Sept., 1886.

sunk by sand pumps, and at first yielded 7,000,000 gallons a day, but soon fell off to only 2,000,000 gallons. Fifteen 4-inch wells were added, and increased the yield to 3,000,000 gallons, but the contractors considered it impossible to get 5,000,000 gallons, and abandoned the contract. In 1894 the Hydraulic Construction Co., of New York, sunk by the jetting method 120 open-end 2-inch wells a mile upstream from the old wells. As the total yield from both well fields was less than 5,000,000 gallons a day, it was necessary to pump river water to supply the 7,000,000-gallon daily consumption in 1895. In July, 1895, B. F. Smith & Co. commenced driving wells in a locality on Merrimack River, and that company made 169 successful wells 27 to 40 feet deep, situated 150 to 350 feet from the river. The daily yield from this area, known as the Lower Boulevard Field, was about 4,000,000 gallons.

Excessive corrosion of lead pipes in the city developed in 1899 and the State board of health attributed it to the high content of carbon dioxide in the water from the Cook wells. Consequently the Cook field and the field a mile upstream on River Meadow Brook were abandoned in 1900. Fifty-two wells driven in 1900 and 125 driven in 1901 supply the Upper Boulevard station. The system was adequate for the demand in 1902 and 1903, but the supply began to decrease, and from 1904 to 1911 it was found necessary to use the Cook wells. A deterioration in quality, due to overdraft, was coincident with the decrease in supply. In 1911 there were added 118 new wells in the Boulevard field, so that there were then 450 wells available in this area, allowing for a few that had been abandoned. The addition of these wells counteracted the overdraft and for several years the supply was satisfactory.

The wells that have been sunk since 1900 are of the closed-end type. They are of 2½-inch extra-heavy iron pipe with a bottom section 38 inches long, in which are bored 180 half-inch holes. A heavy brass wire wound spirally around the pipe separates it from a brass screen with vertical slots, 20 to the inch horizontally and 6 to the inch vertically. The bottom is screwed into a cast-iron driving point 4⅛ inches in diameter that protects the strainer from abrasion. The wells are driven with a heavy drop hammer. As the formation into which the wells are driven is of fine grain, the strainers have to be cleaned at intervals. Each casing is capped at the surface, and a connection with the suction main is made below the cap through a T. In general, the wells are staggered 12 feet apart on alternate sides of the suction main and 4 feet distant from it.

That the water comes in large part from the river is shown by the seasonal range of the temperature from 45° to 65° F., which is much more pronounced than that of true ground water. The de-

terioration upon overdraft is presumably due to the fact that the water is then retained a shorter time in the earth and consequently loses less of its impurities.[1]

NEWBURYPORT, MASS.

At Newburyport, Mass., a flat gravelly or sandy stretch, which looked rather promising as a source of water supply, yielded little water when test wells were sunk. As there was urgent need of a water supply a plan was worked out by which water from an impure source was pumped onto the plain and was recovered by driven wells after having percolated some distance. The quality of the water is stated to have been greatly improved by this filtration process.[2]

NEWTON, MASS.

A filter basin 1,575 feet long by 10 to 88 feet wide at Newton, Mass., lies parallel to Charles River and intercepts the underflow to the river. This amounts to an excavation in the bottom of which are driven wells that collect the water. The system also includes a number of driven wells on the other side of the river.[3]

PLAINVILLE, CONN.

In 1909 the Plainville Water Co. decided to install a ground-water supply for use in summer because of the annoying algal growths in the surface supply then used. Test wells on a site near Quinnipiac River showed an underflow toward the river. Thirty driven wells, each 3 inches in diameter, were put down in two rows of 15 wells each at right angles to the direction of underflow. The depths range from 25 to 30 feet. Tests indicated a capacity of 40 gallons a minute for each well. The pump has a capacity of 500 gallons a minute, and if operated 10 or 12 hours a day it provides sufficient water. Despite the heavy draft on the ground water there has been no permanent reduction of the supply, and though the water level is depressed by the day's pumpage it recovers overnight. The water is excellent, though a little harder than the reservoir water.[4]

QUALITY OF GROUND WATER.

ANALYSES AND ASSAYS.

The chemical studies made in connection with this report comprise 3 complete analyses, 22 partial analyses, and 42 laboratory assays made by Alfred A. Chambers and C. H. Kidwell in the

[1] Thomas, R. J., The Lowell Waterworks and some recent improvements: New England Waterworks Assoc. Jour., vol. 27, March, 1913.

[2] Johnston, W. S., Ground waters as sources of public water supply: New England Waterworks Assoc. Jour., vol. 23, pp. 401–434, 1909.

[3] Baker, W. N., Manual of American waterworks, p. 53, 1897.

[4] Palmer, H. S., Ground water in the Southington-Granby area, Conn.: U. S. Geol. Survey Water-Supply Paper 466 (in press).

water-resources laboratory of the United States Geological Survey. These are divided among the three areas as follows: Norwalk area, 14 analyses and 23 assays; Suffield area, 7 analyses and 12 assays; Glastonbury area, 4 analyses and 7 assays. The quantities are reported in parts per million.

Constituents determined by analysis.—In 22 of the 25 analyses the following constituents were chemically determined: Silica (SiO_2), iron (Fe), calcium (Ca), magnesium (Mg), carbonate radicle (CO_3), bicarbonate radicle (HCO_3), sulphate radicle (SO_4), chloride radicle (Cl), nitrate radicle (NO_3), and total dissolved solids at 180° C. In the three remaining analyses (Ridgefield Nos. 15 and 16 and Westport No. 39) sodium (Na) and potassium (K) were also determined.

In the assays the following constituents were chemically determined: Iron (Fe), carbonate radicle (CO_3), bicarbonate radicle (HCO_3), sulphate radicle (SO_4), chloride radicle (Cl), and total hardness in the conventional terms of $CaCO_3$.

Constituents computed.—In the partial analyses the following quantities were computed: Sodium and potassium taken together (Na+K), total hardness as $CaCO_3$, scale-forming ingredients, foaming ingredients, and the probability of corrosion in steam boilers. In three of the analyses, as noted above, sodium and potassium were determined independently by chemical methods instead of by computation.

The computation of sodium and potassium was made by calculating the sum of the reacting values of the acid radicles (CO_3, HCO_3, SO_4, Cl, and NO_3) and subtracting from it the sum of the reacting values of calcium and magnesium (Ca and Mg). The reacting value of a constituent is its capacity to enter into chemical combination and is equal to the amount of the constituent present multiplied by its valence and divided by its molecular weight. The excess of the acid radicles is considered to be equivalent to and in equilibrium with the sodium and potassium. They were computed on the hypothesis that only sodium was present, by dividing the difference between the reacting values of the acids and bases by the reacting value of an amount of sodium equivalent to one part per million. The result is reported as if it were sodium and potassium.

Total hardness was computed in the conventional terms of calcium carbonate ($CaCO_3$) by the following formula given by Dole:[1]

$$H=2.5\ Ca+4.1\ Mg$$

The computations of s, f, and c, which represent respectively the scale-forming ingredients, the foaming ingredients, and the prob-

[1] Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, p. 45, 1916.

ability of corrosion, were made by the following formulas given by Dole.[1]

$$s = Sm + Cm + 2.95\ Ca + 1.66\ Mg$$
$$f = 2.7\ Na$$
$$c = 0.0821\ Mg - 0.0333\ CO_3 - 0.0164\ HCO_3$$

The symbols Sm and Cm represent suspended matter and colloidal matter, respectively, and are expressed in parts per million.

In the assays the same quantities were computed except total hardness which was determined, and in addition the total solids were computed. In the assays the following formula given by Dole[2] was used to compute the values of the alkalies, sodium and potassium (Na+K).

$$Na = 0.83\ CO_3 + 0.41\ HCO_3 + 0.71\ Cl + 0.52\ SO_4 - 0.5\ H$$

The symbols represent the parts per million of alkali (sodium and potassium) and the carbonate, bicarbonate, chloride, sulphate, and total hardness found by the assay.

The total solids were computed by the following approximate formula given by Dole:[3]

$$T.\ S. = SiO_2 + 1.73\ CO_3 + 0.86\ HCO_3 + 1.48\ SO_4 + 1.62\ Cl$$

The symbols represent the parts per million of silica and the carbonate, bicarbonate, sulphate, and chloride radicles. In applying this formula it is necessary to set some arbitrary value for the silica. Inasmuch as the average silica content of the analyses of ground waters in this report is 23 parts per million, 25 parts per million, a convenient round number on the safe side, was taken as the arbitrary value for silica. The estimate of solids is rough, and only two significant figures are reported.

The factor for scale-forming ingredients, s, was computed according to an approximate formula given by Dole.[4]

$$s = Cm + H$$

The symbols represent the parts per million of colloidal matter and of total hardness in terms of $CaCO_3$. Inasmuch as the colloidal matter is essentially the same as the silica, the above equation has been used in the equivalent form

$$s = SiO_2 + H$$

The value of silica was taken arbitrarily as 25 parts per million, as in the computation of total solids. The unknown but variable ratio between calcium and magnesium introduces a further error.

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[1] Idem, p. 65. See also Water-Supply Paper 375, pp. 163–164, 1916.

[2] Op. cit., p. 57.

[3] Idem, p. 81.

[4] Idem, p. 66.

The results are therefore reported to the nearest 10 if above 100 and to the nearest 5 if below 100.

The same formula was used for computing foaming ingredients in the assays as in the analyses. Formulas upon which the classification of waters for boiler use as regards their corrosive tendency are based are different with the assays from those used with the analyses. (See section on interpretation of analyses, p. 57.)

PROBABLE ACCURACY OF ANALYSES AND ASSAYS.

The analyses in this report were all made according to the methods outlined in Water-Supply Paper 236,[1] which gives also a discussion of accuracy of methods and results based on both theoretical and practical considerations. The subjoined table, taken from this discussion, gives the limits which have been used for rejecting analytical data. Acceptance or rejection of analyses in which sodium and potassium (Na+K) are calculated is based on the difference between the sum of the constituents and the total solids. The sum is computed by adding the amounts of the various constituents, first converting bicarbonate to carbonate $\frac{HCO_3}{2.03}=CO_3$. Differences between the sum and total solids greater than the limit set forth in the above table are generally due to inaccuracy of work or errors of computation, though the presence of organic matter may cause serious differences. Combining or reacting values have also been used to check analyses in which sodium and potassium have been determined. The percentage difference between the reacting values of the acids and bases is computed and compared with the proper figure according to the total solids in the table. Analyses showing errors greater than the limits given by the table were rejected or the waters were reanalyzed.

Criteria for rejecting analytical data.

Dissolved solids (parts per million).		Maximum excess of total dissolved solids over sum of constituents (parts per million).	Maximum excess of sum of constituents over total dissolved solids (parts per million).	Maximum error of combining values (per cent).
Not less than—	Less than—			
....	50	15	5	15
50	100	20	6	7
100	200	30	8	5
200	500	40	12	4
500	1,000	50	....	3
1,000	2,000	....	....	2

[1] Dole, R. B., The quality of surface waters in the United States, pt. 1, pp. 9–23, 28–39, 1909.

Assays are approximations which serve to show, by means of a few determinations rapidly made and by computations based on these determinations, the general character of a water rather than the exact amount of each constituent present. It has been shown that the values of a water for domestic, irrigation, and boiler use may be determined by such assays with a degree of accuracy which is sufficient for practical purposes.[1]

CHEMICAL CHARACTER OF WATER.

The essential points in describing the chemical character of a water are, first, the concentration or total amount of mineral matter contained therein and, second, the nature of the chief constituents. As regards the bases present the most important distinction is that between calcium and magnesium on the one hand and sodium and potassium on the other. Calcium and magnesium are members of the chemical group known as alkali earths and have many similar properties, so that they are in contrast with sodium and potassium, which belong to the group of alkali metals and are in turn mutually closely related. As regards the acid radicles present, distinction is made between the carbonate, sulphate, and chloride radicles. As carbonate and bicarbonate are always in chemical equilibrium and carbonate is the more stable, they are grouped together, and bicarbonate is reduced to carbonate by dividing by 2.03. The acid and basic radicles are not balanced against one another directly but are first reduced to reacting values by multiplying by the valence and dividing by the sum of the atomic weights of the constituent atoms. The reacting values of the several acid and basic radicles are compared and used in applying the following classification:[2]

Classification of water by chemical character.

$$\left.\begin{array}{l}\text{Calcium (Ca)}\\ \text{Sodium (Na)}\end{array}\right\}\quad\left\{\begin{array}{l}\text{Carbonate } (CO_3)\\ \text{Sulphate } (SO_4)\\ \text{Chloride (Cl)}\end{array}\right.$$

The designation "calcium" indicates that calcium and magnesium predominate among the bases, and "sodium" indicates that sodium and potassium predominate. The designation "carbonate," "sulphate," or "chloride" shows which acid radicle predominates. Combination of the two terms classifies the water by type, and the classification can be abbreviated by the use of symbols—for example, "$Ca\text{-}CO_3$" for a calcium-carbonate water.

[1] Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, pp. 43–50, 1916.

[2] Idem, p. 80.

INTERPRETATION OF ANALYSES AND ASSAYS.

In addition to the chemical classification discussed in the preceding section, the analyses and assays have been interpreted as regards their suitability for boiler and domestic use.

Mineralization and hardness.—Waters may be classified according to the concentration of dissolved matter in them—that is, the degree of mineralization—and according to their hardness or soap-consuming powers. Waters may be considered as low in mineralization if they contain less than 150 parts per million of dissolved solids; moderately mineralized if they contain from 150 to 500 parts per million; highly mineralized if they contain from 500 to 2,000; and very highly mineralized if they contain over 2,000 parts per million.[1]

Hardness in water is due chiefly to the presence of calcium and magnesium, which unite with soap, forming insoluble compounds that have no cleansing value. Hardness is measured by the soap-consuming capacity of a water and can be expressed as an equivalent of calcium carbonate ($CaCO_3$). It can be computed from the amounts of calcium and magnesium in the water or can be determined by actual testing with standard soap solution. Waters that contain less than 50 parts per million of hardness measured as calcium carbonate may be considered very soft; waters that contain from 50 to 100 parts, soft; waters that contain 100 to 300 parts, hard; and waters that contain over 300 parts, very hard.

Quality for boiler use.—Three kinds of trouble in the operation of boilers are due to unfavorable features of the water—the formation of scale, foaming, and corrosion. Scale is mineral matter deposited within the boiler as a result of evaporation and heating under pressure. These deposits increase the consumption of fuel, as they are bad conductors of heat, and they also decrease the cubic capacity of the boiler. They are a source of expense and a potential cause of explosions. Scale is formed of the substances in the feed water that are insoluble or that become so under the usual conditions of boiler operation. It includes all the suspended matter, the silica, iron, aluminum, calcium (principally as carbonate and sulphate), and magnesium (principally as oxide but also as carbonate). Formulas for the computation of scale-forming ingredients are given on page 54.

Foaming is the rising of water in the boiler, particularly into the steam space above the normal water level, and it is intimately connected with priming, which is the passage of water mixed with steam from the boiler into the engine. Foaming results when anything pre-

[1] Idem, p. 82.

vents the free escape of the nascent steam from the water. It is believed to be due principally to sodium and potassium, which remain in solution after most of the other bases are precipitated as scale and which increase the surface tension of the water. The increased surface tension tends to prevent the steam bubbles from bursting and escaping. Other factors undoubtedly affect or cause foaming, but sodium and potassium are the chief agents. The principal ill effects of foaming are that the water carried over with the unbroken steam bubbles may injure the engine, and that it may cause dangerously violent boiling. Where waters that foam badly are used it is necessary to "blow off" the water at frequent intervals to get rid of the rather concentrated sodium and potassium. A formula for computing the amount of foaming ingredients is given on page 54.

Corrosion, or "pitting," is caused chiefly by the solvent action of free acids on the iron of the boiler. Many acids have this effect, but the chief ones are those freed by the deposition of hydrates of iron, aluminum, and especially of magnesium. The acid radicles that were in equilibrium with these bases may pass into equilibrium with other bases, thus setting free equivalent quantities of CO_3 and HCO_3; or they may decompose carbonates and bicarbonates that have been deposited as scale; or they may combine with the iron of the boiler, thus causing corrosion; or they may do any two or all three of these. Even with the most complete analysis this action can be predicted only as a probability. If the acid thus freed exceeds the amount required to decompose the carbonates and bicarbonates it corrodes the iron. The danger from corrosion obviously lies in the thinning and weakening of the boiler, which may result in explosion. The formula for the corrosive tendency[1] used in computations based on the analyses expresses the relation between the reacting values of magnesium and the radicles involving carbonic acid. If c is positive the water is corrosive, for this represents an excess of magnesium over carbonate and bicarbonate. If $c-0.0499$ Ca (the reacting value of the calcium) is negative the carbonate and bicarbonate taken together can hold both the calcium and magnesium, and corrosion will not be caused by the mineral constituents. If $c-0.0499$ Ca is positive the ability of the carbonate and bicarbonate to hold the calcium and magnesium is uncertain and corrosion is uncertain. These three conditions may be represented by the symbols C (corrosive), N (noncorrosive), and (?) (corrosion uncertain). (For formulas see page 54.)

In working with the assays it is necessary to restate the conditions, as the amounts of calcium and magnesium are unknown. One-fiftieth of the total hardness is equivalent to the reacting value of calcium and magnesium, and H divided by 230 (or 0.004 H) is equiva-

[1] Mendenhall, W. C., Dole, R. B., and Stabler, Herman, op. cit., p. 65.

lent to the reacting value of magnesium on the assumption that Ca=6 Mg, a ratio which gives magnesium its smallest probable value relative to calcium. The reacting values of carbonate and bicarbonate are represented, respectively, by 0.033 CO_3 and 0.016 HCO_3, each coefficient being the ratio of the valence of the radicle to its molecular weight. The following propositions result:

If 0.033 CO_3+0.016 HCO_3>0.02 H, then the mineral matter will not cause corrosion.

If 0.033 CO_3+0.016 HCO_3<0.004 H, then the water is corrosive.

If 0.033 CO_3+0.016 HCO_3<0.02 H but>0.004 H, then corrosion is uncertain.

Scale formation, foaming, and corrosion are the principal criteria in rating waters for boiler use, but their evaluation is a matter of personal experience and judgment. The committee on water service of the American Railway Engineering and Maintenance of Way Association has offered two classifications by which waters in their raw state may be approximately rated, but, as their report states, "it is difficult to define by analysis sharply the line between good and bad water for steam-making purposes." Their tables, which are given below with the amounts recalculated in terms of parts per million, were used in rating the waters for this report. In every case the less favorable of the two ratings was given.

Ratings of water for boiler use according to incrusting and corroding ingredients and to foaming ingredients.[a]

Incrusting and corroding ingredients.			Foaming ingredients.		
Parts per million.		Classification.[b]	Parts per million.		Classification.[c]
More than—	Not more than—		More than—	Not more than—	
....	90	Good.	....	150	Good.
90	200	Fair.	150	250	Fair
200	430	Poor.	250	400	Bad.
430	....	Bad.	400	....	Very bad.

[a] Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, p. 67, 1916.
[b] Am. Railway Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.
[c] Idem, vol. 9, p. 131, 1908.

Quality of water for domestic use.—Waters whose hardness does not exceed 200 parts per million and which are sufficiently low in mineral matter to be palatable are satisfactory for drinking and cooking. Although waters high in hardening constituents can be used for drinking they are unsatisfactory for cooking and laundering. Hardness exceeding 1,500 parts per million makes water undesirable for cooking, and water much softer than that consumes

excessive quantities of soap in washing. Approximately 200 parts per million of carbonate, 250 parts of chloride, and 300 parts of sulphate can be detected by taste. Considerably higher amounts of these constituents can be tolerated by a human being, but more than 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate is apparently intolerable to most people. However, local conditions and individual preference largely determine the significance of the terms "good" or "bad" as applied to the mineral quality of water for domestic use.

CONTAMINATION.

Water supplies may become contaminated in various ways, chiefly by industrial and manufacturing wastes, by the washing in of surface drainage, or by sewage. The objectionable materials derived from industrial wastes are largely chemical; those derived from surface wash or sewage are organic, the germs of disease. As industrial wastes do not frequently pollute ground-water supplies, they are passed over briefly in this report. Sea water causes serious trouble in parts of the Norwalk area but need not be considered except in a strip along the shore of Long Island Sound. Sewage is a very serious danger and is of various sorts, including animal excreta, human excreta, and kitchen wastes. It is only through a nearly criminal neglect of the elementary principles of hygiene and sanitation that these substances ever get into water supplies. Wells should never be constructed where there is any possibility of underflow from barnyards, latrines, or kitchen drains. No spring that is thus wrongly situated should be used. No barnyard, pigpen, latrine, or kitchen drain should be built in a situation where it might pollute a well or spring. No rule can be laid down as to the direction of flow of the underground water, though it is in general the same as the direction of slope of the surface of the ground. Similarly no rule can be given as to what may be considered a safe distance between a well or spring and a source of pollution. To be safe this distance should always be made as great as possible.

The excreta of all animals, especially of human beings, contain considerable amounts of chloride that has been taken into the body in the form of sodium chloride (common salt) and discharged in the same condition. The human excreta are richer in chloride because human beings are able to obtain more salt. Chloride is a normal constituent of all waters in Connecticut and is derived in part from the sea by the agency of the wind, which carries inland small amounts of salt-laden spray. There is, then, for every point a "normal" amount of chloride, the amount that is normally carried there by the wind. Along the shore of Long Island Sound it is rather large,

but inland it is small. The amount of chloride in normal waters of Connecticut has been determined for different parts of the State and shown on maps[1] indicating the normal distribution of chloride by means of isochlors, or lines defining areas within which the waters in their natural state contain certain definite amounts of chloride. In the Suffield area the normal chloride is about 1.5 parts per million, and in the Glastonbury area about 2 parts. In the inland portion (Ridgefield) of the Norwalk area the normal chloride is from 2 to 2.5 parts per million, but along the shore it is much greater. This wind-blown salt is almost the only normal source of chloride for waters derived from the crystalline rocks, the till, or the stratified drift, though it is possible that some of the sandstone waters have dissolved small amounts of salt that was included in the sediments during their deposition. Chloride may be readily and accurately determined by the chemist. Any water which has an undue amount of chloride should be looked on with suspicion and should not be used in its raw state unless frequent bacteriologic examination shows it to be indubitably safe. Many of the cases of typhoid fever that have occurred in the State have been traced to water supplies contaminated by human excreta.

Nitrates may also be considered as indicators of contamination by sewage, for nitrogen exists in all excreta as nitrates or in forms readily convertible to nitrates through oxidation. Waters that contain more than 6 or 7 parts per million of nitrate should be looked on with suspicion and subjected to bacteriologic examination. A content of more than 12 parts per million of nitrate usually indicates gross contamination. Waters in which the total mineral content is unusually high may be approved though the nitrate is a little high, whereas in waters with a low total mineral content less nitrate is allowable. In general waters that are high in both nitrate and chloride indicate contamination by human excreta, whereas waters that are high in nitrate but contain only a normal amount of chloride indicate contamination by live stock. Although waters that contain less than 6 parts per million of chloride are probably free from animal contamination, waters that have unusually little or no nitrate should be treated with suspicion, for sewage often contains denitrifying bacteria which destroy the nitrates and convert them to nitrites and perhaps to free nitrogen and ammonia. Because of the comparatively unstable character of the nitrogen in the nitrates, the nitrate content is a far less reliable indicator of pollution than chloride, which is chemically very stable.

[1] Smith, H. E., Connecticut State Board of Health Rept. for 1902, pp. 227–242. Gregory, H. E., and Ellis, E. E., Underground-water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, p. 168, 1909.

It is possible in general to locate the source of excessive chloride or nitrate by inspection of the surroundings of the well or spring from which the sample for analysis was obtained. In fact, it is often possible on simple examination of the premises to predict that analysis will show excessive chloride or nitrate.

In addition to making safe the location of a well, or spring by seeing to it that no potential source of pollution is near, precautions should be taken to prevent the entrance of surface wash. The ground around dug wells should be filled in and tamped enough to make rain water and drippings flow away from them and not back into them. An excellent protection is a concrete apron several feet wide on all sides of the well and sloping away from it. Cattle should be kept away from wells and springs by a fence, and they should be watered at a trough some distance away. Drilled wells should have the iron casing set firmly into the bedrock to prevent the entrance of shallow ground water, and the casing should extend a foot above the ground to keep out surface wash. A little extra care, labor, and expense in the protection of a water supply will be well repaid by the feeling of safety gained, if not by the saving of doctors' bills and perhaps even of life.

TABULATIONS.

The results of the analyses and assays and the computations based on them are tabulated for each town included in this report.

Tables of analyses and assays comparing the waters from the various water-bearing formations are given on page 64. Within each table the data have been grouped according to the geologic formation from which the waters were obtained, and the average amounts of each constituent are reported, together with the number of analyses or assays used in obtaining the average. Figure 12 is a graphic representation of the table comparing the groups of analyses. The analyses of dolomite water and beach-sand water are not plotted except as they are involved in the general average of the 25 analyses.

With the possible exception of the analyses of waters from stratified drift and till, the number of analyses available is too small to represent adequately the average composition of waters from the various water-bearing formations. As it is inadvisable to draw generalizations from these data regarding the quality of water by formations, the graph (see fig. 12) and tables of averages are presented with that understanding and are not intended to be interpreted as conclusive.

The presence of carbonate in waters is dependent upon the condition of its chemical equilibrium with bicarbonate. As the

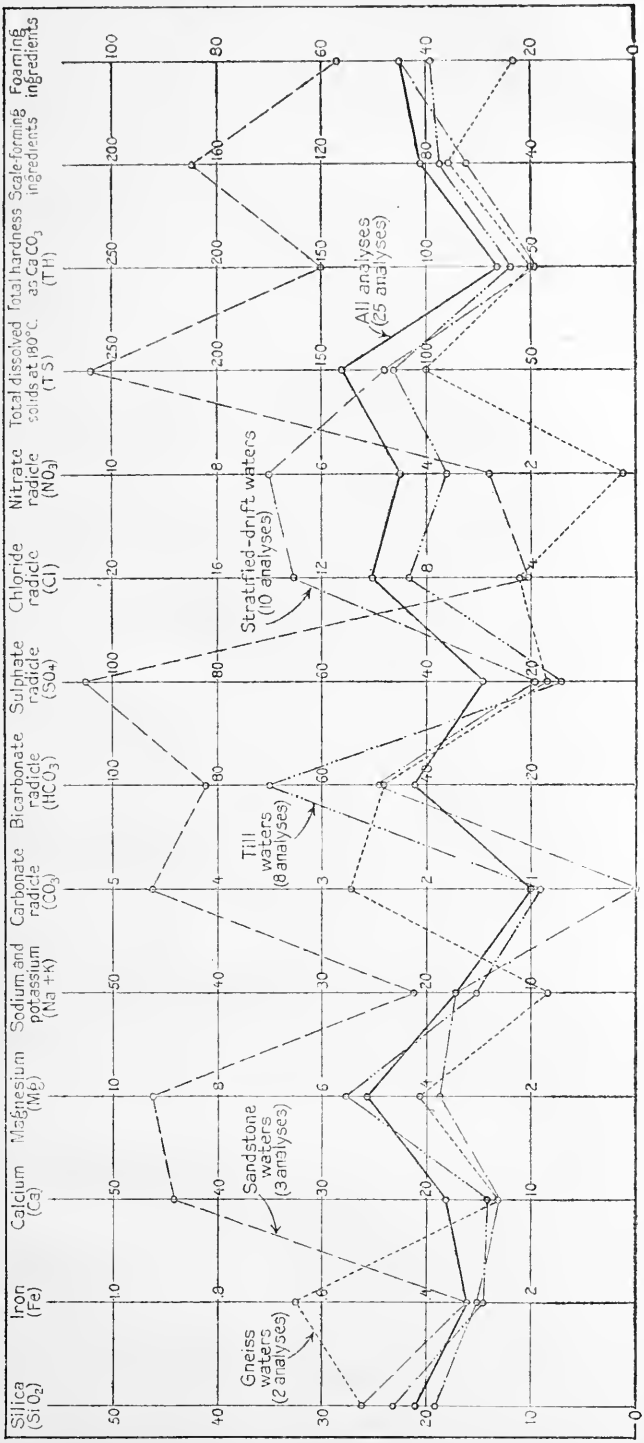

FIGURE 12.—Graph showing average composition, in parts per million, of waters analyzed, grouped according to water-bearing formations.

equilibrium is a variable, separate averages of carbonate and bicarbonate are often difficult of interpretation. Thus it will be noticed in the table of averages of analyses that some of the waters contained no carbonate at the time of analysis, although it is possible that under certain conditions carbonate might be present in them. As a basis for more careful comparison of the waters it would be advisable to convert the bicarbonate into carbonate by dividing the figure for bicarbonate by 2.03.

Averages of groups of analyses of waters from the water-bearing formations of the Norwalk, Suffield, and Glastonbury areas, Connecticut.

[Parts per million except as otherwise stated.]

Formation.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total solids at 180° C.	Total hardness as $CaCO_3$.	Scale-forming ingredients.	Foaming ingredients.	Number of analyses averaged in group.
Gneiss	26	0.65	13	4.1	8.2	2.7	48	17	4.4	0.22	100	50	72	23	2
Dolomite	17	.14	18	4.6	18	.0	77	14	6.2	.08	114	64	78	49	a1
Sandstone	26	.32	44	9.2	21	4.6	82	105	4.1	2.8	260	150	170	57	3
Stratified drift	19	.30	13	3.7	17	.0	49	19	13	7.0	119	48	64	45	10
Till	23	.29	14	5.5	15	.9	70	14	8.7	3.6	115	59	75	39	8
Beach sand	11	.32	22	6.0	37	.0	90	49	30	4.4	218	80	86	100	a1
Average of 25 analyses	21	.32	18	5.1	17	1.0	42	29	10	4.5	140	66	82	45	....

a Only analysis available from this formation.

Averages of groups of assays of waters from the various water-bearing formations of the Norwalk, Suffield, and Glastonbury areas, Connecticut.

[Parts per million except as otherwise stated.]

Formation.	Iron (Fe).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Total solids.	Total hardness as $CaCO_3$.	Scale-forming ingredients.	Foaming ingredients.	Number of assays averaged in group.
Gneiss	0.32	30	3.3	76	21	48	204	99	125	80	3
Sandstone	.25	12	4.0	135	22	8.6	193	129	153	33	3
Stratified drift	.22	13	.0	44	16	17	113	52	77	36	20
Till	.21	14	.9	109	14	12	161	96	120	37	16
Average of 42 assays	.22	14	.9	78	16	17	144	77	102	39	42

TEMPERATURE OF GROUND WATER.

The temperature of ground water depends on and tends to become the same as that of the material through which it circulates. A layer a few inches thick at the top of the ground varies greatly in temperature every 24 hours, owing to the heating effect of the sun in the daytime and the radiation of heat at night. This phenomenon is particu-

larly noticeable early in the spring, when the ground freezes hard at night but thaws and becomes soft and muddy during the day. At a moderate depth these diurnal variations become negligible and only seasonal fluctuations of temperature occur. These seasonal fluctuations of temperature correspond to the freezing of the ground to a depth of several feet in the fall and the spring thawing of this ground, which has remained frozen through the winter. At a still greater depth there are not even seasonal fluctuations and the temperature is uniform the year around. The depth of this zone of no seasonal fluctuation of temperature is believed to be 50 or 60 feet. Its temperature tends to be the same as the mean annual temperature of the locality, and water which circulates through it tends to have the same temperature as the mean annual temperature. In the southern part of the Norwalk area the normal ground-water temperature is probably about 49.5° F., the mean annual temperature at New Haven, a place of similar situation.[1] In the northern part of the Norwalk area the normal ground-water temperature is perhaps 1° lower because of the greater elevation and the greater distance from the ameliorating influence of Long Island Sound. In the Suffield area the normal ground-water temperature is probably about 48.5°, the mean annual temperature at Hartford. This will also hold for the northern or lowland part of the Glastonbury area, but in the southern or highland part the normal ground-water temperature will be half a degree or a degree lower. In the region of no seasonal fluctuation of temperature there is a rather uniform increase of temperature with increasing depth, due to the internal heat of the earth. This amounts to 1° F. for every 50 to 100 feet increase in depth, so that deep drilled wells usually get slightly warmer water.

Springs and wells whose waters have traveled a considerable distance in the zone of no seasonal fluctuation should have this temperature uniformly the year around. If the circulation has been in large part in the zone of seasonal fluctuation the water will be warmer in summer than in winter. It seems probable that springs on north slopes, where the heating effect of the sun is at a minimum, would be a little cooler than normal, and springs on south slopes, where insolation is at a maximum, would be a little warmer than normal. Because of this factor and because of the increase of temperature in depth, the actual temperature of the water is of less importance in determining whether water has circulated near the surface or at considerable depth than the uniformity of the temperature the year around.

[1] Summaries of climatological data by sections: U. S. Weather Bureau Bull. 2, pt. 2, sec. 105, p. 11, 1905.

DETAILED DESCRIPTIONS OF TOWNS.

DARIEN.

AREA, POPULATION, AND INDUSTRIES.

Darien is on the southern border of Fairfield County, between Stamford and Norwalk. Long Island Sound forms the south boundary and Noroton River the west boundary. The east boundary in part follows Fivemile River. The area of the town is about 13 square miles, of which 3 square miles, or about 25 per cent of the whole area, is wooded.

The territory was taken from Stamford and made a separate town in 1820. In 1910 the population was 3,946, an increase of 830 in the decade from 1900. The mean density of population is 312 to the square mile. The following table gives the population at each census and the per cent of change during the preceding decade:

Population of Darien.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1820	1,126		1870	1,808	+ 6
1830	1,212	+ 8	1880	1,949	+ 8
1840	1,080	−11	1890	2,276	+17
1850	1,454	+35	1900	3,116	+37
1860	1,705	+17	1910	3,946	+27

[a] Connecticut Register and Manual, 1915, p. 653.

There has been growth in every decade except that from 1830 to 1840. In the following decade, 1840 to 1850, there was an unusually large growth, due presumably to the opening of the New York & New Haven Railroad in 1849. During the last two decades there has been a relatively great increase in the population which is dependent in large part on the proximity of New York City. A number of extensive and beautiful residential estates have been established in Darien, and it is probable that this sort of development will continue. The growth for the next few decades will probably be moderate and steady. Darien and Noroton are the principal settlements. Both have stations on the main line of the New York, New Haven & Hartford Railroad. A trolley line connects Stamford and Norwalk and runs through Darien. Post offices are maintained at Darien, Noroton, and Noroton Heights, and the outlying districts are served by rural delivery. The Boston Post Road, one of the State trunk-line highways, runs east and west near the south boundary of the town. About 4 miles of its length is in Darien, and it connects all the shore towns between Bridgeport and New York. In addition, there are about 60 miles of road worked by the town and a number of miles of semipublic roads privately maintained. The town roads

A. ESTUARY IN DARIEN, CONN.

B. SECTION OF STRATIFIED DRIFT, DARIEN, CONN.

are excellent and are constructed in part of macadam and in part of gravel.

The principal industries of Darien are agriculture and oyster farming. The residential estates directly and indirectly furnish employment to many of the inhabitants.

SURFACE FEATURES.

Darien, although it lies near sea level, must be included in the western highlands of Connecticut because of the character of its bedrock and the topography developed thereon. The strongly ridged and furrowed surface of erosion has been depressed and in part submerged. Small estuaries alternate with peninsulas and make a very irregular shore line. The maximum elevation, about 260 feet above sea level, is found on several ridges near the north boundary.

A long cycle of erosion had reduced this region to a plain. Subsequently this plain was uplifted and dissected, forming ridges and elongated hills that trend about north and south. The hills were somewhat worn down and the valleys partly filled with débris. In a strip of country about a mile wide along the shore there are many small knobs of solid rock which rise above the water level of the bays and above the salt marshes. It is believed that since its glaciation the region has been depressed relative to sea level, that the bays and estuaries are drowned valleys, and that the peninsulas are partly submerged ridges. Plate VIII, *A*, a view in the southeastern part of the town, shows an estuary bordered by salt marshes above which rise small, wooded, rocky hills.

The eastern part of the town is drained by Fivemile River and the western by Noroton River. The central part of the town is drained by Stony Brook and a second unnamed brook. These streams rise just beyond the north boundary of the town and are about 5 miles long. There are also a few short brooks in the south part of the town that drain directly into the Sound.

WATER-BEARING FORMATIONS.

Schist and gneiss.—Three bedrock formations have been recognized in Darien[1]—Becket granite gneiss, Danbury granodiorite gneiss, and Thomaston granite gneiss.

The Becket granite gneiss, which underlies a small area along the north portion of the Fivemile Brook boundary, is of complex origin—that is, it is a schist, into which a great deal of igneous material has been injected, thus altering its character. The rock consists of ill-

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

defined alternating bands of gray schist and sheets of granitic and hornblendic material.

The Thomaston granite gneiss is the bedrock in a small area in the northwest corner of the town and a larger area around and south of Noroton. Originally it was granite composed essentially of quartz, feldspar, and mica with minor quantities of accessory minerals. Subsequent mashing has given it a moderately pronounced gneissic texture expressed by dark bands that are relatively rich in black mica. The degree to which this texture is developed varies from place to place.

The Danbury granodiorite gneiss is similar to the Thomaston granite gneiss except that it has hornblende in addition to quartz, feldspar, and mica. Its gneissic character is in general less pronounced but is everywhere clearly distinguishable. This formation underlies most of Darien.

The water-bearing properties of the three bedrocks are so much alike that they may be considered together. Interstitial water is almost if not entirely absent. A number of elongated openings, fissures, and joint cracks exist in these rocks. Water which has fallen as rain and snow and been absorbed by the unconsolidated mantle rock may be transmitted ultimately to the intricate network of intersecting fissures in the bedrock. Wells drilled into the rock are apt to intersect one or more such water-bearing crevices and to obtain moderate supplies. In general the fissures are more abundant in the higher zones of the bedrock than farther down. It is therefore better policy to abandon a well that is unsuccessful in the first 300 feet and to try in a new place, rather than to drill deeper. This is shown by the following table compiled from the data on drilled wells given on page 74. The wells have been grouped according to depth, and the ratio of the yield (in gallons per minute) to the depth computed. The number of gallons per minute obtained for each foot drilled is in general less in the deeper groups than in the shallower groups.

Relation of yield of drilled wells to depth.

Depth of wells (feet)	0–99.	100–199.	200–299.	300–399.	400–499.	500 and over.
Number of wells	7	8	3	3	5	4
Total depth ... feet	529	1,093	694	1,027	2,145	3,468
Total yield ... gallons per minute	42.5	39	14.5	23.5	94	32.5
Average yield ... do	6	5	5	8	19	7
Yield per foot of drilling ... do	.080	.036	.021	.023	.044	.009

The depths of 40 drilled wells in Darien were ascertained. They range from 65 to 1,465 feet and average 266 feet. The yields of 30 of

these wells average 8 gallons a minute. A few of them yielded no water, and the greatest yield was 50 gallons a minute.

No general statement can be made as to the direction and extent of the water-bearing fissures in the town. Systems of fissures, or a set of two or three systems, are developed locally. One system is roughly horizontal and is cut by one or two steeply inclined fissure systems. One of the inclined systems tends to dominate the other. It is said that on the east side of Long Neck Point there is more probability of obtaining salt water in deep wells than on the west side. A possible explanation of this condition is suggested in figure 13. A system of strong fissures striking north and dipping west would be likely to carry sea water into wells near the east shore, for the fissure cut by such wells crops out under the waters of the Sound. The fissures cut by drilled wells on the west side of the peninsula would be fissures that crop out above sea level. The outcrops of bedrock on Long Neck Point are so few that the direction of the fissure systems could not be ascertained.

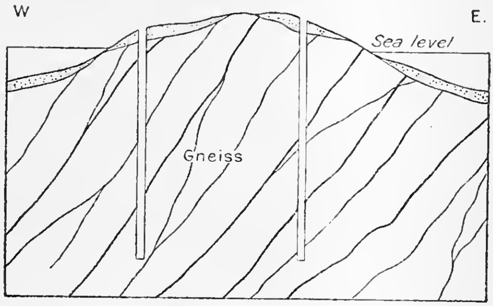

FIGURE 13.—Hypothetical section of Long Neck Point, Darien.

It is impossible to make a general statement as to how near the shore a well may be drilled with certainty of avoiding pollution by sea water, because of the great irregularity of the fissure systems. However, it seems inadvisable to drill within 500 feet of the shore, or on a small island.

Till.—Overlying the consolidated bedrock in Darien are found three types of mantle rock—till, stratified drift, and the muds of the salt marshes, the last of which, however, are not an available source of water supply.

Till is the material formed by the plowing and scraping action of the great ice sheet that overrode the region in glacial time. It consists of a thoroughly mixed mass of débris of all kinds of material in fragments which range in size from the finest of rock-flour particles to boulders weighing tons. It comprises a matrix of sand, silt, and rock flour in which are embedded pebbles, cobbles, and boulders. Between the smaller particles are minute interstices that are capable of absorbing rain water, of storing it, and of giving it out slowly to wells and springs. Wells dug in till, unless unfavorably situated, will yield small but fairly reliable supplies of water. Forty-three

such wells were measured at Darien in September, 1916. Data regarding the depths found are given in the following table:

Summary of wells dug in till in Darien.

	Total depth.	Depth to water.	Depth of water.
	Feet.	*Feet.*	*Feet.*
Maximum	55.0	35.0	20.0
Minimum	6.7	3.1	.7
Average	19.6	13.3	6.4

Twenty-six of the wells were said to be unfailing, and eight were said to fail. The reliability of the remaining nine wells was not ascertained.

Stratified drift.—Along Norwalk River and Fivemile River and in other valley bottoms till is absent and stratified drift constitutes the mantle rock. This drift is a water-laid deposit formed for the most part by the reworking of the materials of the till. The different sizes have been sorted from one another and laid in distinct beds and lenses. Because of the elimination to a great extent of fine particles from the spaces between the larger ones, this type of deposit is more porous than till. It not only can contain more water, but because of the greater size of the passages it will transmit water more readily. This greater porosity makes it a better source of water than till, except where the body of stratified drift is in a bad topographic situation from which the water may readily seep away. The wells of the Tokeneke Water Co. and two domestic wells (Nos. 28 and 29) in Darien are dug in stratified drift. One spring, No. 72 (see map, Pl. II), is at the foot of a terrace scarp and at the inner edge of the flood plain of Fivemile River. This spring was yielding about a gallon a minute in September and had a temperature of 51° F.

QUALITY OF GROUND WATER.

The accompanying table gives the results of two analyses and two assays of samples of ground waters collected in the town of Darien. The waters are low in mineral content, are very soft, and are suitable for boiler use. In so far as may be determined by chemical investigation of the mineral content of these waters they are acceptable for domestic use. No. 16 and the composite sample, No. 71 and 71A, are calcium-carbonate in type. Nos. 49 and 54 are sodium-carbonate waters.

Chemical composition and classification of ground waters in Darien.[a]

[Parts per million. Collected Dec. 9, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond with those used on Pl. II.]

	Analyses.[b]		Assays.[c]	
	16	71, 71A	49[d]	51
Silica (SiO_2)	33	20	.....	.....
Iron (Fe)	.40	.11	0.31	0.25
Calcium (Ca)	9.6	10	.....	.....
Magnesium (Mg)	1.5	3.3	.....	.....
Sodium and potassium (Na+K)[e]	9.1	11	15	11
Carbonate radicle (CO_3)	5.3	.0	.0	.0
Bicarbonate radicle (HCO_3)	51	28	30	27
Sulphate radicle (SO_4)	5.9	16	22	8.0
Chloride radicle (Cl)	3.6	9.5	4.2	4.2
Nitrate radicle (NO_3)	.43	.77	.....	.....
Total dissolved solids at 180° C.	98	90	[c] 80	[c] 67
Total hardness as $CaCO_3$	[e] 42	[e] 38	23	14
Scale-forming constituents[c]	69	55	50	40
Foaming constituents[c]	25	30	40	30
Chemical character	Ca-CO_3	Ca-CO_3	Na-CO_3	Na-CO_3
Probability of corrosion[f]	(?)	(?)	N	N
Quality for boiler use	Good	Good.	Good.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 72-74.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Collected December 7, 1916.
[e] Computed.
[f] Based on computed quantity; (?)=corrosion uncertain; N=noncorrosive.

PUBLIC WATER SUPPLIES.

Two companies supply the residents of Darien with water. The Noroton Water Co. has been supplying Darien, Noroton, and Noroton Heights in Darien and a few customers in Glenbrook in Stamford since 1911. It buys its water by meter from the Stamford Water Co. and distributes it by gravity under a pressure of 55 to 65 pounds to the square inch through 15.6 miles of main pipe to 96 hydrants and 406 metered service taps.[1] The 2,500 people that are supplied consume an average of 194,000 gallons a day. Mr. Harold H. Mead, the superintendent, stated in 1916 that the winter consumption is only two-thirds as great as the summer consumption. The company owns two reservoir sites, one in North Stamford and one in New Canaan, which will eventually be used.

The Tokeneke Water Co. is a subsidiary of the Tokeneke Corporation which has made an extensive land development in the southeast corner of the town. Service was begun in December, 1909. At present water from two large dug wells in stratified drift is pumped to a steel standpipe of 46,500 gallons capacity, and is distributed by gravity through 3.5 miles of mains to 16 hydrants

[1] Connecticut Public Utilities Commission Rept., 1917.

and 81 service taps. The pressure is from 40 to 60 pounds to the square inch. There are two single-acting triplex Gould pumps of $6\frac{1}{2}$-inch bore and 8-inch stroke, driven by upright single-cylinder gasoline engines. The capacity of each pump is said by Mr. Charles F. Barker, the superintendent, to be 150 gallons a minute. A small single-acting triplex Gould pump, of $3\frac{1}{2}$-inch bore and 4-inch stroke, that has a capacity of 25 gallons a minute and is driven by an electric motor, is used as an auxiliary.

The site of the wells was originally a terrace, but in excavating gravel for road building it has been cut down nearly to the level of the flood plain. Plate VIII, *B*, shows the fact of the remaining portion of the terrace and the character of the stratified drift at this point. Plate IX, *A*, shows the pumping plant and the roofs of the wells. At the left is well No. 2 (No. 71A on the map, Pl. II), which is 32 feet in diameter and 13 feet deep, at the center is the pump house, and at the right is well No. 1 (No. 71 on the map), which is 15 feet in diameter and 10 feet deep. According to Mr. Barker, if pumping is done at the rate of 150 gallons a minute and water is taken from both wells the drawdown, or depression of the water level, is about 2 feet. If well No. 1 is pumped alone the water is depressed to the suction limit in 3 or 4 hours. If well No. 2 is pumped alone the drawdown is about $2\frac{1}{2}$ feet, but the water in well No. 1, 100 feet away, is lowered about 6 inches. Mr. Barker estimates the daily consumption in the summer months to be 60,000 to 70,000 gallons a day, but only a third as much in winter.

RECORDS OF WELLS.

Wells dug in till in Darien.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1		Slope	130	25.0	21.8	3.2	Windlass rig	Nonfailing.
2		do	130	24.1	16.6	7.5	do	Do.
3		do	205	18.6	10.2	8.4	do	Do.
4	Wm. E. Clark	Plateau	205	26.2	10.1	16.1	Chain pump	Do.
5		do	205	19.3	10.1	9.2	do	
6		Slope	240	16.1	6.2	9.9	Windlass rig and house pump.	
7	H. V. Miller	do	235	18.5	14.1	4.4	Chain pump	Fails.
8		do	230	20.9	13.9	7.0	Windlass rig	Nonfailing.
9		Plateau	190	17.9	14.7	3.2	Chain pump	Do.
10		Slope	210	17.6	9.3	8.3	do	Do.
11		do	180	15.1	9.5	5.6	Windlass rig	Do.
12	John Straks	Plain	170	17.6	14.2	3.4	Windlass rig and house pump.	Do.
13		do	150	14.8	12.8	2.0	Deep-well pump	Do.
14		Slope	185	20.7	15.8	4.9	Chain pump	Abandoned.
17	E. C. Bates	do	160	20.5	10.2	10.3	House pump	Nonfailing.
19		Plain	75	17.0	15.2	1.8	No rig	Do.
22		Slope	75	14.2	8.7	5.5	Chain pump	Do.
24		do	75	19.0	16.1	2.9	Windlass rig	Do.
25		do	50	26.3	23.2	3.1	do	Do.

A. PLANT OF THE TOKENEKE WATER CO., DARIEN, CONN.

B. STRATIFIED DRIFT PLAIN, EAST GRANBY, CONN.

Wells dug in till in Darien—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
26	J. C. Uhrlaub	Hill top	180	35.0	20.0	15.0	(*a*)	Nonfailing.
27		Slope	85	17.8	14.3	3.5	Windlass rig	Do.
30		Plateau	165	30.6	16.8	13.8	do	Fails.
31		Slope	160	27.5	13.4	14.1	Chain pump	Nonfailing.
33		Plain	80	13.9	8.7	5.2	Windlass rig	
34		do	70	12.2	11.1	1.1	Two-bucket rig.	Do.
36		Slope	30	16.4	11.3	5.1	Windlass rig	Do.
37		Plain	90	6.7	3.1	3.6	House pump	
39		Slope	140	23.5	15.7	7.8	Chain pump	Do.
41		do	115	14.4	13.0	1.4	do	Fails.
49	Misses Brady	do	65	11.4	8.0	3.4	House pump	Fails. For assay see p. 71.
50		do	80	18.5	12.3	6.2	Chain pump	
51		Plain	40	12.5	3.2	9.3	do	Nonfailing.
53		do	10	9.0	4.5	4.5	One-bucket rig	
54	James Kenealy	Slope	11	10.5	7.6	2.9	Chain pump	Nonfailing; fresh water though only 125 feet from well No. 53. For assay see p. 71.
60	James A. Trowbridge.	Ridge	35	55.0	35.0	20.0		Fails.
60A	do	Slope		38.0	20.0	18.0		Do.(*b*)
60B	do	do		27.0	20.0	7.0		Do.(*c*)
62		do	110	33.1	20.1	13.0	Windlass rig	Nonfailing.
66		Plain	30	12.1	8.2	3.9	do	Do.
67		Slope	45	17.2	13.3	3.9	Chain pump	Do.(*d*)
75		do	50	16.0	12.7	3.3	do	
76		do	25	13.0	12.3	.7	do	
77		Plain	15	8.5	7.2	1.3	House pump	Fails.

a Well is 20 feet in diameter. Pumped by electricity to tank.
b Well is 300 feet east of well No 60.
c Well is 150 feet south of well No. 60.
d Well is in a basin between two rock ledges.

Wells dug in stratified drift in Darien.

No. on Pl. II.	Owner	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
28		Slope	25	25.0	23.2	1.8	House pump	
29		Plain	20	23.9	19.3	4.6	do	Nonfailing.
71	Tokeneke Water Co.	do	15	10.0	6.5	3.5	(*a*)	Nonfailing. For analysis see p. 71.[b]
71A	do	do	15	13.0	8.0	5.0	(*c*)	Do.

a Well is 15 feet in diameter; will yield 150 gallons a minute.
b Sample collected for analysis is composite of Nos. 71 and 71A.
c Well is 32 feet in diameter; will yield 150 gallons a minute. There is some interference between this well and well No. 71, which is 200 feet farther south.

Drilled wells in Darien.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Galls.*	
15	Col. Edgerton	Slope	155	......	......	......	......	......	
16	W. C. Humbert	do	115	125	48	13	6	5	Water from gneiss. For analysis see p. 71.
18	Ernest Barthol	do	110	71	7	16	6	2	
20	Sarah F. Leeson	do	105	110	6	15	6	15	
21	F. M. Smith	do	95	75	30	20	6	3	
23	W. R. S. Bates	do	45	189	14	20	6	3½	
32	John A. Weed	do	90	200	......	......	......	Slight.	
35	C. W. Maury	do	30	400	......	......	8	26	
38	Fordfield estate	Plateau	120	150	......	15	6	(a)	
40	Soldiers' Home	Hill	140	503	13	15	8	26	(b).
40A	do	do	140	425	12	(c)	8	50	(c).
42	Forbes	Slope	50	......	......	......	......	......	
43	Henry D. Weed	do	20	175	......	......	......	2	
44	......	do	15	65	......	5	......	(d)	
45	......	Plain	10	75	......	......	......	(e)	
46	W. M. Weed	Island	15	67	2	15	......	½	Slightly brackish.
47	John H. Shipway	do	10	(f)	......	......	......	......	
48	Eliza Birdsell	Slope	60	110	13	13	6	3½	
52	Fred Wecke	do	30	264	17	20	6	4	
55	Wm. Ziegler, jr	do	40	350	......	......	......	14	
56	do	Island	30	1,465	......	......	......	3	
56A	do.[g]	......	......	1,000	......	......	......	Dry.	
56B	do.[h]	......	......	200	......	......	......	1½	Water salty.
57	do	Island	......	700	......	......	......	......	Do.
58	John Cort	Slope	25	130	0	......	......	......	
59	H. C. Fleitman	do	25	230	5	......	......	9	
61	Mrs. H. P. Stokes	Ridge	25	500	20	20	6	3½	(i).
61A	do	do	25	350	20	15	6	6	(j).
61B	do	do	25	460	......	......	6	10	(k).
61C	do	do	25	450	20	......	6	Dry.	(l).
63	A. B. Noxon	Slope	75	66½	9	18	6	2	
64	Henry Brencher	do	70	78	18	15	6	10	
65	Caroline F. Perry	do	75	75	9	60	6	5	
68	L. J. Mead	do	60	153	6	20	6	3	
69	Miss Zada Dean	do	60	103	2	15	6	5	
70	Dr. J. F. Pentecost	do	40	410	5	20	......	8	(m).
73	C. D. Albrecht	do	65	128	20	18	6	2	
74	Mrs. S. C. Petty	do	50	96½	5	10	6	20	
78	Fred H. Rowan	Plain	15	327	9	10	6	3½	

[a] Abundant.
[b] For further description see U. S. Geol. Survey Water-Supply Paper 232, p. 90, 1909.
[c] Op. cit., p. 91.
[d] Water potable, though slightly brackish.
[e] Salt water, although 500 feet from shore.
[f] Four drilled wells on this island. Two were drilled to between 75 and 100 feet deep, where the drills were blocked by slanting fissures. The other wells are about 200 feet deep and yield salty water.
[g] Well is 150 feet west of well No. 56.
[h] Well is 300 feet northwest of well No. 56.
[i] Drilled in 1902; yielded 10 gallons a minute of fair water at first. The yield soon dropped to 4½ gallons a minute, and in four years to 3½ gallons a minute; 175 feet from shore.
[j] Drilled in 1904; 150 feet southwest of well No. 61 and 125 feet from shore. Water is salty.
[k] Yielded 18 gallons a minute at a depth of 360 feet at first, but after four months it failed. Deepening to 460 feet gave a yield of 1 or 2 gallons. Seventy-five pounds of 70 per cent dynamite was exploded at the bottom of the well, but with no effect. A second shot of 50 pounds brought a yield of 10 gallons a minute. This water was fresh at first, but later became brackish. Well is 220 feet south of well No. 61.
[l] Well is 175 feet from shore and 100 feet south of well No. 61.
[m] Well yields 1½ gallons a minute at depth of 75 feet; 5 to 6 at depth of 150 feet; 7½ at depth of 200 feet; and 8 to 10 at full depth of 410 feet.

NEW CANAAN.

AREA, POPULATION, AND INDUSTRIES.

New Canaan, in Fairfield County, Conn., is one of the second tier of towns north of Long Island Sound. To the north is part of Westchester County, N. Y., on the west is the north part of Stamford, on the south is Darien, on the southeast Norwalk, and on the

east Wilton. Silvermine Brook forms part of the eastern boundary and Rippowam River part of the western boundary. The total area of the town is 23 square miles, of which 11 square miles, or 45 per cent, is wooded. The woods are for the most part in the valleys and on the steep slopes, whereas the broad hilltops and ridge crests are cleared.

The territory which now constitutes New Canaan was taken from Stamford and Norwalk in 1801 and incorporated as a separate town. The population in 1910 was 3,667, an increase of 701 from 1900. The borough of New Canaan had about 1,672 inhabitants. The density of population of the town as a whole was 160 to the square mile. The following table shows the population at each census and the percentage of change in the decade preceding:

Population of New Canaan, 1810–1910.[a]

Year.	Population.	Per cent of change.	Year.	Population.	Per cent of change.
1810	1,597	....	1870	2,479	−10
1820	1,689	+ 6	1880	2,673	+ 7
1830	1,830	+ 8	1890	2,701	+ 1
1840	2,217	+21	1900	2,968	+10
1850	2,600	+17	1910	3,667	+24
1860	2,771	+ 7			

[a] Connecticut Register and Manual, 1919, p. 639.

There has been growth in every decade except that from 1860 to 1870, when there was a decrease for which no explanation is apparent. The large increase from 1830 to 1850 may be due in part to the opening of the New York & New Haven Railroad in 1849. The increase from 1890 to 1910 is presumably the result of the development of this region as a commuting residential district tributary to New York City. It is probable that this growth will continue, especially if a proposed railroad from Greenwich through the north part of Stamford and New Canaan to Ridgefield and Danbury is constructed. At all events such a possibility must be borne in mind in planning future development and utilization of the ground and surface water resources of the region.

The only built-up settlement in New Canaan is the borough of New Canaan, incorporated in 1889. There is about 70 miles of road in the town, which is in general well kept up, and there is a good deal of tar-bound macadam. New Canaan is reached by the electrified New Canaan branch of the New York, New Haven & Hartford Railroad, which joins the main line at Stamford. Stages run between New Canaan and Norwalk. There is a post office at the borough, and rural-delivery routes serve the outlying parts of the

town. The principal industries are agriculture, the raising of nursery stock, and the manufacture of shirts and overalls and of wire goods.

SURFACE FEATURES.

New Canaan lies on an upland which is dissected by valleys 150 to 200 feet deep that lead south-southwestward. The interstream spaces are broad ridges with gently rolling crests and steep flanks. The profile in figure 14 is drawn across the town a little north of the borough and shows the broad plateau cut by the shallow valley of Fivemile River, and bounded by the deeper valleys of Rippowam and Silvermine River. Formerly the surface was nearly level, but it has been tilted to the south-southeast. This tilting has established the general south-southeast courses of the rivers. Tributaries of Rippowam River drain about 5 square miles in the northwest corner of the town and the headwaters of Noroton River 7 square miles in the southwest corner. A north-south strip 1 to 1½ miles wide through

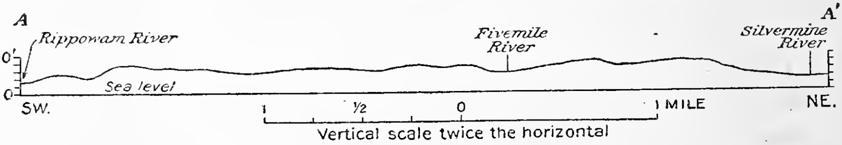

FIGURE 14.—Profile across New Canaan (A–A' on Pls. II and III), showing undulating plateau and the valleys cut below it.

the middle of the town is tributary to Fivemile River, which rises within the town limits. A similar strip along the east boundary is drained by Silvermine River. Near the head of Fivemile River is the reservoir of the New Canaan Water Co., and on Silvermine is the Grupe reservoir of the first taxing district of the city of Norwalk.

The lowest points in New Canaan are those where Noroton and Fivemile rivers cross the boundary about 115 feet above sea level, in the southwest and southeast corners of the town. The highest point is near the middle of the north boundary and is 620 feet above sea level. There is thus a range of elevation of about 500 feet.

WATER-BEARING FORMATIONS.

Schist and gneiss.—The bedrocks which underlie New Canaan have been identified as belonging to four formations.[1] Underlying an area of 2 square miles in the northwest corner of the town is the Berkshire schist. It is a medium to dark gray well-banded schist, composed essentially of black mica and quartz with some garnet, feldspar, and other accessory minerals. The small mica scales have

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

in large part been segregated and turned parallel to one another, so that they form dark bands that alternate with quartz bands and give the rock its fissile, schistose character. There are many thin veins of white and pink granitic material injected along and across the cleavage planes.

The bedrock of a circular area a mile in diameter in the north part of the borough and of an area half as large in the southeast corner of the town is the Danbury granodiorite gneiss. This gneiss is a moderately coarse igneous rock composed essentially of feldspar and quartz with black mica or hornblende or both. In this region there is a tendency for certain of the feldspar crystals to be larger than others and thus to give the rock a porphyritic character. Hornblende is more abundant than elsewhere in the formation. Since its original consolidation from a state of igneous fusion, the rock has undergone metamorphism and has been changed to a gneiss. The gneissic texture is similar to the schistose texture of the Berkshire schist in character but is far less well developed. There is less mica, and the hornblende is less cleavable, so that the rock splits into thicker slabs and with more difficulty.

An area of about a square mile in the southeast corner of the town is underlain by the Becket granite gneiss. According to Gregory,[1] it was probably originally a

> granite which has been injected at different times and subjected to intense metamorphism while yet deeply buried within the earth. On this hypothesis the more granitoid phases are most like the original rock, and the schistose phases are most metamorphosed. The hornblendic and granitic beds were intruded before or during the chief metamorphic movement, and owe their position and alinement to the forces that produced the main foliation. Veins of quartz and pegmatite were intruded after most of the metamorphism had taken place, and certain intrusions indicate even a later stage of igneous activity.

That it is of igneous origin, however, is not certain, for the evidence of its original character has been largely destroyed by metamorphism.

By far the greater part of the town is underlain by the Thomaston granite gneiss. It is a true granite in that the dominant minerals are quartz, feldspar, and black mica, but like the other rocks of the region a gneissic texture has been imposed on it by metamorphism, as is shown by the bands rich in dark mica which alternate with bands rich in light quartz and feldspar. In some places phenocrysts of feldspar, which give the rock a porphyritic character, are developed. The rock is light gray in general, but some parts have a pinkish tinge.

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[1] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 65, 1906.

The capacities of these four rock types for carrying water are about the same and may be discussed together. Because of their low porosity there is no appreciable amount of interstitial water. The schists are probably a little more porous than the gneisses because of the presence of thin flat openings between the flakes of mica, but even this is inconsequential. The crustal disturbances to which this region has been repeatedly subjected have produced many joints and fissures which constitute an intricately interconnecting network of narrow but extensive channels. Other joints are due to shrinkage during the initial consolidation of the rock. When rain falls on the ground a portion of it is absorbed and slowly percolates downward. Most of this water, when it reaches the bedrock surface, will move approximately horizontally, but some will find its way into the joint system. In the upper zones of the bedrock the fissures are far more abundant than at greater depths, where they tend to be closed by the weight of the overlying rock. The water in the joint system may be recovered by drilled wells. It is highly probable that at any specific point one or more water-bearing fissures will be intersected before drilling beyond 250 to 300 feet. If none is cut it is better to try again in a new place than to drill deeper, for it is far less probable that a fissure will be cut between 300 and 600 feet in the old place. The depth of the drilled wells in New Canaan for which data were obtained averages 173 feet and ranges from 86 to 300 feet. The yield of 14 wells averages 23 gallons a minute and ranges from 2 to 70 gallons. A few dug wells blasted down into rock also draw water from fissures, but they are not satisfactory in general. The fissures very near the surface of bedrock are very apt to fail in drought, but the blasted cavity is of some value in that it acts as a reservoir and stores some water.

Till.—Everywhere in New Canaan, except in parts of the valley floors and where ledges of rock outcrop, the bedrock is covered by a mantle of till. The depth to bedrock in 13 of the drilled wells tabulated below averages 37 feet and ranges from 7 to 79 feet. These figures give some idea of the thickness of the till mantle. The till or boulder clay, or "hardpan" as it is locally called, is of glacial origin. The continental glacier which overrode this region from north to south plowed up and scraped away the soft rock and residual soil and even removed some of the deeper unweathered rock. Projecting ledges and knobs of rock were torn away. The rock surface was smoothed, grooved, and polished by rock fragments embedded in the ice, and they in turn crushed, beveled, and polished one another. The resulting material, a heterogeneous mixture of pieces of rocks of many kinds and of all sizes from the very small

particles of rock flour up to boulders weighing several tons, was plastered over the glaciated surface. Deposition was particularly concentrated in depressions and against the slopes of ledges and sharp ridges.

The intimate mixing of particles that vary greatly in size makes the product low in porosity. There are no openings within the pebbles and boulders that could hold water, and the spaces between them are filled with smaller particles. Moreover, the presence of fine material means that the spaces that do exist are very small. However, there is a very appreciable pore space, and a considerable amount of rain water is absorbed and held. On account of the small size of the pores the water is transmitted very slowly, but wells dug in till will obtain supplies that are as a rule fairly reliable. Sixty-five such wells were visited in September and October, 1916, in New Canaan. The measurements made of the wells are tabulated on pages 81–82. The following table summarizes the data:

Summary of wells dug in till in New Canaan.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	40.5	29.5	23.8
Minimum	7.8	5.2	0.5
Average	19.6	14.4	5.2

The reliability of 51 of these wells was ascertained: 33 were said to be nonfailing and 18 to fail. The springs in the table on page 83, with the exception of No. 56, are in till.

Stratified drift.—Stratified drift, which may replace till as the mantle rock, is found in New Canaan only in parts of the valley floors. The map (Pl. III) shows the areas of stratified drift along Rippowam, Fivemile, and Silvermine rivers. This type of deposit has been formed by the action of running water as is shown by the well-washed, sorted, and stratified character of the material. The source of the material is in large part till, but a little of it has undoubtedly been derived directly from the bedrock. The agent has been for the most part the streams that now occupy the valleys. In other parts of the State large volumes of melt water, derived from the receding glacier, built up extensive deposits of stratified drift. However, the questions of the precise source of the material and of the particular transporting agency are not essential to a consideration of the deposits as a source of ground water. The important facts are its character and distribution. It is char-

acterized by sorting into distinct beds within which the particles are of relatively uniform size. Different beds and even adjacent beds are of very dissimilar coarseness. The absence of small particles from the interstices of the larger ones makes a very porous deposit capable of holding and rapidly transmitting a large amount of water, so stratified drift is an excellent source of ground water. Where the slopes are relatively steep the movement of water through stratified drift may be so rapid that wells in it may fail in dry seasons. No wells in stratified drift were visited in New Canaan. Spring 56 (see map, Pl. II, and table, p. 83) is in stratified drift.

QUALITY OF GROUND WATER.

The subjoined table gives the results of two analyses and three assays of samples of ground water collected in the town of New Canaan. The waters are low in mineral content except No. 68, which is moderately mineralized. Nos. 11, 18, and 62 are very soft; No. 35 is soft; and No. 68 is hard in comparison with other waters of this area, though it is not hard as rated by general standards. In so far as mineral content may determine it, these waters are good for domestic use. All are good for boiler use except No. 68, which is rather high in scale-forming ingredients and is therefore rated as fair. The waters are calcium-carbonate in type except Nos. 11 and 62, which are sodium-carbonate waters.

Chemical composition and classification of ground waters in New Canaan.[a]

[Parts per million; collected Dec. 9, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. II.]

	Analyses.[b]		Assays.[c]		
	11	35	18	62	68
Silica (SiO_2)	23	29			
Iron (Fe)	.34	.18	Trace.	0.07	0.78
Calcium (Ca)	6.7	14			
Magnesium (Mg)	2.9	4.7			
Sodium and potassium (Na+K)[d]	11	15	7.	12	10
Carbonate radicle (CO_3)	.0	.0	.0	.0	10
Bicarbonate radicle (HCO_3)	24	68	31	38	119
Sulphate radicle (SO_4)	16	13	9.0	7.0	12
Chloride radicle (Cl)	4.6	12	4.8	5.6	6.1
Nitrate radicle (NO_3)	12	1.9			
Total dissolved solids at 180° C	85	122	[d] 73	[d] 77	[d] 170
Total hardness as $CaCO_3$	[d] 29	[d] 54	28	22	115
Scale-forming constituents[d]	48	78	55	45	140
Foaming constituents[d]	30	40	20	30	30
Chemical character	Na—CO_3	Ca—CO_3	Ca—CO_3	Na—CO_3	Ca—CO_3
Probability of corrosion[e]	(?)	N	(?)	N	(?)
Quality for boiler use	Good.	Good.	Good.	Good.	Fair.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 81-83.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pages 52-60.
[d] Computed.
[e] Based on computed quautity; (?)=corrosion uncertain; N=noncorrosive.

PUBLIC WATER SUPPLY.

The New Canaan Water Co. has supplied residents of the village with water since 1895. The company has a reservoir of 70,000,000 gallons capacity on Fivemile River formed by a core-wall dam about 45 feet high and 400 feet long. The water is distributed from the reservoir by gravity through 9½ miles of main pipe, 52 hydrants, and 512 service taps. The pressure in the village is about 50 pounds to the square inch. About 2,000 people are supplied, and consume about 250,000 gallons a day on the average. The water is filtered, and occasional analyses are made.[1]

If the demands on the system increase very greatly they will be met only with great difficulty, for most of the drainage basins in the region are already in use or their use has been planned for. Good supplies could probably be developed in the deposits of stratified drift along Fivemile River.

RECORDS OF WELLS AND SPRINGS.

Wells dug in till in New Canaan.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Slope.......	360	23.4	18.3	5.1	Windlass rig....	Nonfailing.
2	....	.....do.....	340	14.3	12.7	1.6	One-bucket rig..	Do.
3	....	.....do.....	300	15.1	12.1	3.0	Sweep rig.......	Do.
4	Ellsworth Waters.	.....do.....	360	26.9	19.9	7.0	House pump....	Do.
6	Carl Schneider....	.....do.....	425	18.6	13.6	5.0	Two-bucket rig and house pump.	Fails. Blasted into rock.
7	....	.....do.....	420	22.1	19.8	2.3	Drain pump.....	
8	....	.....do.....	375	16.4	12.5	3.9	.....do..........	Fails.
10	....	.....do.....	465	17.6	7.6	10.0	.....do..........	Nonfailing.
11	F. C. Fladd.......	.....do.....	485	17.8	13.9	3.9	Windlass rig....	Fails. For analysis see p. 80.
12	....	.....do.....	470	32.5	22.4	10.1	.....do..........	
14	....	.....do.....	405	21.2	7.7	13.5	House pump....	Nonfailing.
16	....	Plateau....	350	16.6	8.7	7.9	Drain pump....	
17	....	Slope.......	470	14.9	14.4	0.5	Windlass rig....	Fails.
19	....	.....do.....	490	10.9	8.9	2.0	Two-bucket rig..	Do.
20	....	.....do.....	490	12.5	9.3	3.2	Windlass rig....	Fails. Rock bottom.
21	....	.....do.....	455	17.2	14.0	3.2	Two-bucket rig..	Fails.
22	....	.....do.....	455	14.8	10.6	4.2	Sweep rig.......	Do.
23	....	.....do.....	380	13.6	12.5	1.1	One-bucket rig..	
25	Town Farm.......	.....do.....	465	25.1	17.1	8.0	Two-bucket rig and house pump.	Fails.[a]
26	....	.....do.....	300	28.8	27.0	1.8	Windlass rig....	Nonfailing.
27	....	.....do.....	410	31.1	29.5	1.6	.....do..........	Fails.
28	....	Hilltop.....	430	15.8	11.3	4.5	Two-bucket rig..	Nonfailing.
29	....	Slope......	250	19.2	17.0	2.2	.....do..........	Fails.
30	....	.....do.....	260	15.8	12.4	3.4	Windlass rig....	Do.
33	....	.....do.....	260	13.9	10.6	3.3	.....do..........	
34	....	Hilltop.....	370	20.7	13.4	7.3	Sweep rig and house pump.	Nonfailing.
35	A. S. Jerry........	Slope......	340	21.9	16.7	5.2	.....do..........	Fails. For analysis see p. 80.
36	....	Hilltop.....	365	25.9	19.0	6.9	Chain pump....	Nonfailing.
37	....	Plain......	300	10.1	6.8	3.3	House pump....	Do.
38	....	Plateau....	300	15.9	11.4	4.5	.....do..........	Fails.
39	....	Slope......	285	29.0	5.2	23.8	.....do..........	Nonfailing.
40	....	.....do.....	365	10.8	6.2	4.6	Windlass rig....	
41	....	.....do.....	315	20.4	17.7	2.7	.....do..........	Do.

[a] Well is 15 feet in ledge. Cost about $300 to deepen it 8 feet.

[1] Rept. Connecticut Public Utilities Commission, 1917.

Wells dug in till in New Canaan—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
42		Slope	320	40.5	24.3	16.2	Windlass rig	Nonfailing.
43		Plateau	325	24.9	16.2	8.7	Two-bucket rig	
44	C. F. Stevens	Slope	210	15.9	13.2	2.7	Windlass rig	Do.
45		do	170	16.5	13.5	3.0	Two-bucket rig	Do.
46		do	150	23.3	22.0	1.3	Two-bucket rig and house pump.	Do.
47		do	400	27.4	14.0	13.4	do	Do.
48		do	345	10.3	7.4	2.9	Two-bucket rig	
49		do	280	8.3	5.9	2.4	Chain pump	Nonfailing.
50	J. M. Wassing	do	270	16.8	12.5	4.3	Windlass rig	Do.
51		do	275	27.0	17.3	9.7	Two-bucket rig	Do.
52		do	255	13.1	10.3	2.8	Chain pump	
53		do	240	23.5	14.7	8.8	Two-bucket rig	Do.
54		do	200	15.6	13.4	2.2	do	
55		do	240	7.8	5.9	1.9	Windlass rig	Do.
58		do	175	25.5	20.0	5.5	Two-bucket rig	Do.
59		Knoll	205	25.1	20.5	4.6	Windlass rig	
60		do	180	16.0	9.5	6.5	One-bucket rig	Fails.
61		Slope	180	28.2	21.4	6.8	Two-bucket rig and house pump.	Nonfailing.
62		do	190	24.3	19.7	4.6	do	Nonfailing. For assay see p. 80.
65		do	230	29.5	10.8	10.8	Windlass rig	
66		do	185	22.0	20.7	1.3	do	Fails.
67		do	200	13.9	11.6	2.3	Two-bucket rig	Do.
69		Plain	260	21.2	16.8	4.4	Counterbalancing and air-pressure system.	Nonfailing.
70		Slope	200	16.9	15.2	1.7	Windlass rig	
71		do	190	21.0	18.8	2.2	do	Fails.
73		do	180	12.2	9.4	2.8	do	Nonfailing.
74	School	Hilltop	300	22.1	17.8	4.3	Windlass rig	
75		Slope	320	18.1	11.2	6.4	Two-bucket rig and house pump.	
76	Stephen Hoyt's Sons Co.	Swale	320	20.0	6.0	13.0	[a]	Do.
77		Slope	260	10.4	7.7	2.7	Sweep rig	Nonfailing. Rock bottom.
79		do	230	25.6	23.2	2.4	Windlass rig	Nonfailing.
80		do	310	20.0	15.1	4.9	Two-bucket rig	Do.

[a] Pumped by a steam-driven pump. If 8,000 gallons are pumped the level is depressed about 5 feet, but it regains its former position in about six hours. The inflow is therefore equivalent to about 1,300 gallons an hour, or 20 to 25 gallons a minute.

Drilled wells in New Canaan.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Galls.*	
5	Chapelle	Plateau	415						
9	S. W. Wakeman	Slope	470						
11A	F. C. Fladd	do	485	162	38	23	6	7	
13	George E. Kruger	do	505	105	10	15	6	8	
18	D. H. Hamilton	do	525	199½	7	7	8	32	Water from gneiss. For assay see p. 80.
57	George Brown	do	170	300					
63	Jacobs & Wolf	do	170	205					
64		do	170						
68	Peter B. Chick	Plain	290	121	79	20	6	15	Do.
72	John B. Miller	Slope	205	86	36		6	12	

Drilled wells in New Canaan—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Galls.*	
(a)	Sturgis Coffin	Hill		150	56	4	6	18	
(a)	Mrs. W. E. C. Bradley	do		253	50	8	6	40	
(a)	Taggart	Slope		153	66	20	6	70	
(a)	Miss C. A. Bliss	Hill		150	20	4	6	40	
(a)	Theodore Terrill	do		186	11	9		6	
(a)	Dr. P. H. Williams	do		200	49	5	6	2	
(a)	Mrs. L. D. Alexander	Ridge		248	35	15	5		
(a)	L. P. Child	Hill		156		64	6	15	
(a)	B. Fisher estate	Ridge		130					
(a)	Gray Bros	Slope		104	24	30	6	15	
(b)	Mrs. A. M. Bradley			253		11		40	
(c)	Grace Church	Hill		120		25			

a Not plotted on map. Data from Gregory, H. E., Underground-water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, p. 82, 1909.
b Not plotted on map. Idem, p. 83.
c Not plotted on map. Data from Gregory, H. E., Contributions to the hydrology of eastern United States; Connecticut: U. S. Geol. Survey Water-Supply Paper 102, p. 128, 1904.

Springs in New Canaan.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
			Feet.	*°F.*	*Gallons.*	
15	J. Busslinger	Slope	390			Pumped to house.
24	Town farm	do	430	51	2	
31		Foot of cliff	290	54	½	
32	A. C. Clarkson	Brookside	275	49	1	Air-pressure system.
56		Foot of terrace	180	51	15+	
78		Slope	270	54	½	

NORWALK.

AREA, POPULATION, AND INDUSTRIES.

Norwalk, in Fairfield County, is on Long Island Sound. 32 miles west of New Haven, 40 miles east of New York, and 20 miles south of Danbury. Norwalk River, which rises in Ridgefield, flows through the middle of the town. Fivemile River in part follows the west boundary and in part lies half a mile east of it. The area of the part of the town on the mainland is about 23 square miles, of which about 6 square miles or 25 per cent is wooded. The woodlands are most abundant in the west and north parts of the town. The offshore islands aggregate an area of a third of a square mile.

The territory of Norwalk was purchased from the Indians and a town was incorporated in 1651. The original town included more territory, but from time to time parts have been separated to make new towns. In 1801 New Canaan was made of territory taken in part from Norwalk and in part from Stamford. In 1802 Wilton was taken from Norwalk, and in 1835 part of Norwalk was combined with

parts of Fairfield and Weston to form Westport. The city of South Norwalk was incorporated in 1870 and the city of Norwalk in 1893. Since then they have been combined and made into one city coterminous with the town but divided into five taxing districts. The first district was formerly the city of Norwalk, the second district was formerly the city of South Norwalk, and the third district was formerly the fire district of East Norwalk. The fourth district comprises these three districts, and the fifth district comprises the outlying parts of the town.

The population in 1910 was 24,211, an increase of 4,279 over the 1900 population. The population is concentrated in the city, but if distributed over the whole town would average about 1,070 to the square mile. In 1910 there were 6,954 people in Norwalk and 8,968 in South Norwalk. The following table gives the population at each census since 1756 and the percentage of change in each census period:

Population of Norwalk, 1756 to 1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1756	3,050	....	1840	3,863	+ 2
1774	4,388	[b]+44	1850	4,651	+20
1782	4,051	[c]− 8	1860	7,582	+63
1790	([d])	....	1870	12,119	+60
1800	5,146	[e]+27	1880	13,956	+15
1810	2,983	....	1890	17,747	+27
1820	3,004	+ 1	1900	19,932	+12
1830	3,792	+ 26	1910	24,211	+21

[a] Connecticut Register and Manual, 1919, p. 640.
[b] For a period of 18 years.
[c] For a period of 8 years.
[d] Norwalk was not counted separately but was included with Stamford and Greenwich at this census.
[e] For a period of 20 years.

There has been growth in each period except that from 1774 to 1782. In the decade from 1830 to 1840 there was enough increase to a little more than offset the loss of population by the cession of part of Westport in 1835. In 1849 the New York & New Haven Railroad was opened, and in 1852 the Danbury & Norwalk Railroad. In the two decades from 1850 to 1870 Norwalk nearly trebled in population as manufactures became well established. The population continued to increase steadily and doubled between 1870 and 1910. It is to be expected that the growth will continue.

In addition to Norwalk, South Norwalk, and East Norwalk, which are built up without break, there are four small settlements in the town. Rowayton, in the southwest corner of the town, is in large part a summer settlement. West Norwalk is on Fivemile Brook just south of the New Canaan town line. Winnipauk is a small manufacturing village on Norwalk River 1½ miles north of Norwalk. Cranberry is a little settlement near the northeast corner of the town.

The main line of the New York, New Haven & Hartford Railroad crosses the town near the shore of Long Island Sound and has stations at Rowayton, South Norwalk, and East Norwalk. The Danbury branch, connecting South Norwalk with Danbury, has stations also at Norwalk and Winnipauk. Trolleys connect South Norwalk with Darien and Stamford by way of Rowayton; East Norwalk, Saugatuck, Westport, and Bridgeport; Roton Point; Gregory Point; and Norwalk and Winnipauk. A trunk-line State highway connects with points east and west along the shore, and another follows Norwalk River to Ridgefield and to Danbury. There is automobile-stage service to New Canaan from Norwalk. Post offices are maintained at Norwalk, South Norwalk, and Rowayton, with carrier service in Norwalk, South Norwalk, and East Norwalk. The outlying districts are served by rural delivery.

The principal industries of Norwalk are the manufacture of corsets, shirts, silks, paper and paper goods, brass, rugs, hats, hardware and machinery, boots and shoes, woolen goods, lace, automobile tires, motor trucks, engines, stoves, and stone and earthen ware; shipbuilding; oyster fishing; and agriculture in the outlying districts.

SURFACE FEATURES.

Norwalk is in that portion of the western highlands of Connecticut that lies along the shore of Long Island Sound. The inland portion of the province is a plateau sloping gently to the south-southeast, underlain by intensely folded, crushed, and injected rocks. The plateau has been deeply trenched by streams so that, although the hills and ridges rise to concordant altitudes, the topography is rugged. At the seaward margin these features persist but in a reduced degree. Formerly the land stood higher relative to sea level and Norwalk was well inland, and under such conditions it developed the topographic features characteristic of the present inland. Subsequent depressing of the land has drowned the Norwalk coast. Arms of the sea extend up the valleys making bays of the shorter ones and an estuary of the valley of Norwalk River. The ridges between these drowned valleys are now peninsulas. In the heads of the bays and estuaries the water has but little motion, and deposits of mud have been made. These are the salt marshes that form so prominent a feature of the topography of the Connecticut shore. The greatest elevation in the town, 340 feet above sea level, is on the divide between Silvermine and Norwalk rivers at the Wilton town line.

Fivemile River and Norwalk River are through-flowing streams which with their tributaries drain the west and central parts of the town. On Silvermine River, which enters Norwalk River a little

below Winnipauk, and on Norwalk River there are several small water powers developed. The northeast corner of the town is drained by the headwaters of Stony Brook which crosses into Westport and joins Saugatuck River. There are a few short brooks which drain parts of the shore zone and flow through salt marshes into the Sound.

WATER-BEARING FORMATIONS.

Schist and gneiss.—There are three bedrock formations in Norwalk[1]—the Danbury granodiorite gneiss, which underlies a strip 2 miles long west of Fivemile River; the Becket granite gneiss, underlying the rest of the elevated territory west of Norwalk River; and the Thomaston granite gneiss, underlying the south margin of the town and most of the part east of Norwalk River. There is also an area of Becket granite gneiss half a mile wide and extending a mile along the middle of the Westport boundary.

The Becket granite gneiss underlies much of western Connecticut, and is composed of feldspar, quartz, and black mica which are concentrated in contrasting light and dark layers. These give the rock the banded and cleavable character typical of gneisses. There is some doubt as to whether this rock was originally an igneous or sedimentary rock. The minerals are those defining the granite family of igneous rocks, but certain phases are so highly quartzose as to suggest sandstone. It is possible that a very minor part of the rock is of sedimentary origin but that an extreme amount of igneous material has been added so as to give it a dominantly igneous character. It is a resistant rock and forms a high ridge between Fivemile River and Norwalk River. This ridge is bounded on the west by a valley cut in large part in Danbury granodiorite gneiss, and on the south and east by a lower area of the Thomaston granite gneiss.

The essential constituents of the Danbury granodiorite gneiss are quartz, feldspar, and mica or hornblende or both. Where the mica is the chief dark mineral the rock approaches a true granite in composition, but where hornblende is dominant it becomes a granodiorite. The granodiorite seems to be the variety found most commonly in the southern part of Fairfield County, according to Gregory.[2] Certain of the feldspar crystals tend to be much larger than the other crystals, so the rock has a porphyritic texture on which mashing has superposed a gneissoid texture.

The only essential differences between the Thomaston granite gneiss and the Danbury granodiorite gneiss are that the former contains little or no hornblende and the porphyritic texture is less

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

[2] Gregory, H. E., and Rice, W. N., Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 108, 1906.

prominent. Both are probably younger than the Becket granite gneiss, for they have been altered less by metamorphism.

The capacities of the three types of bedrock for carrying water are substantially the same. Igneous rocks have only negligible amounts of pore space. Moreover, the effect of dynamic metamorphism is to reduce the porosity still more. Therefore we expect to find and actually do find no appreciable amounts of interstitial water in these rocks. It is possible that the minute flat openings between mica flakes in the more schistose phases may contain a little water, but these openings are so small and circulation is so retarded by friction that no valuable supply of water can be obtained from them. Openings of another kind do exist in these rocks and are capable of taking in, transmitting, and again giving out some ground water. These are the rather extensive joints and fissures formed in part by shrinkage of the rock and in part by the mechanical forces which have acted on the rocks. They form a very complicated network of interconnecting fissures better developed near the surface of the bedrock than in depth. The base of the overlying mantle of unconsolidated rock is saturated in most places with water. This water, derived primarily by absorption of rain, works its way through and fills the network of fissures and may be recovered by means of drilled wells. Detailed data concerning a number of such wells in Norwalk are given in the table on page 94. The following table summarizes these data:

Summary of drilled wells in Norwalk.

	Total depth.	Depth to rock.	Depth to water.	Yield in gallons per minute.
	Feet.	*Feet.*	*Feet.*	
Maximum	260	12	20	25
Minimum	45	80	5	½
Average	166	35	12	11

Till.—There are two types of mantle rock in Norwalk from which water is obtained—till and stratified drift. In addition there are the deposits of the salt marshes and beach sands, which would give only salt water. Well No. 95 (see map, Pl. II) is of this type.

The till, which is also called boulder clay and "hardpan," overlies the bedrock of the more elevated portions of the town. The name "hardpan" is descriptive of the physical properties which make it difficult to excavate. The till consists of an intimate and thoroughly heterogeneous mixture of glacial débris, which includes fragments of all conceivable sizes and shapes derived from all the varieties of rock overridden by the ice. Boulders, cobbles, and pebbles torn and scraped off the ledges were carried along by the ice sheet. They were

rubbed against one another and polished, grooved, and broken. Eventually they were embedded in a matrix composed in part of their minute fragments, in part of scrapings from the bedrock, and in part of the soil which had covered the region in preglacial time. The weight of the overlying ice sheet helped to compact the deposit. There are, however, many minute pores in the till, and it is capable of absorbing considerable amounts of rain water, which percolates downward until it reaches the surface of the bedrock. Then part of it may enter the joints of the rock, and part of it may move more or less horizontally along the rock surface. Water may be recovered from the till by means of dug wells into which it will slowly seep. The most abundant supplies are found in a zone a few feet thick just above the bedrock or in lenses of partly washed material which is more porous. Sixty-nine wells dug in till were visited in Norwalk early in October, 1916. Two were found to be dry, and 13 more were said to fail. The dependability of 10 could not be ascertained, but the remaining 44 were said to be nonfailing. The data collected concerning these wells are given in detail in the table on pages 92–93, and are summarized in the following table:

Summary of wells dug in till in Norwalk.

	Total depth.	Depth to water.	Depth of water.
	Feet.	*Feet.*	*Feet.*
Maximum	40.1	29.9	13.8
Minimum	8.4	5.3	.9
Average	19.4	15.0	4.2

Stratified drift.—Deposits of stratified drift are found in the valleys of the streams of Norwalk and are shown on the map (Pl. II). Most of the deposits are narrow, but in the valley of Norwalk River below Winnipauk and in the valley connecting Cranberry and Norwalk there are wider areas. At the seaward margin these deposits blend into the salt-marsh deposits. For the most part they are stream deposits, but some of the more southerly stretches may be beach sands and gravels. Whether of marine or fluviatile origin, these deposits differ from the till described above in that they are well washed and sorted and are laid in separate beds. The elimination of smaller particles from the chinks between the larger ones makes stratified drift highly porous, so that it absorbs and transmits more water. Unless unfavorably situated, as, for example, near the edge of a terrace, wells in stratified drift yield good supplies of water. Measurements of 24 such wells in Norwalk were made and are given in the table on page 93. The reliability of 19 of these wells was ascertained. Only two were said to fail. The data con-

cerning the depths of these wells are summarized in the following table:

Summary of wells dug in stratified drift in Norwalk.

	Total depth.	Depth to water.	Depth of water.
	Feet.	*Feet.*	*Feet.*
Maximum	29.0	26.6	4.0
Minimum	7.7	5.3	1.0
Average	18.8	16.4	2.4

QUALITY OF GROUND WATER.

The subjoined table gives the results of two analyses and three assays of samples of ground water collected in Norwalk in December, 1916. All are low in mineral content except No. 47A, which is moderately mineralized. Nos. 47 and 47A are soft waters, and the other three are very soft. All are acceptable for domestic use so far as their mineral content and chemical character are concerned. No. 47A will give a little trouble with formation of scale if used in boilers, but the rest are classed as good for boiler use. No. 47 is from a well drilled into gneiss and situated very close to the dug well in till from which No. 47A was obtained. A comparison of the two analyses will show that because of the minute character of the particles composing the till, greater opportunity is given for the ground water to take mineral matter into solution. The waters are sodium carbonate in type except No. 47, which is a calcium-carbonate water.

Chemical composition and classification of ground waters in Norwalk.[a]

[Parts per million; collected Dec. 9, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. II.]

	Analyses.[b]		Assays.[c]		
	[d] 47	47A	36	63	91
Silica (SiO_2)	18	27			
Iron (Fe)	.90	.70	Trace.	Trace.	0.11
Calcium (Ca)	17	21			
Magnesium (Mg)	3.7	11			
Sodium and potassium (Na+K)[e]	7.3	25	.8	11	22
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	44	127	21	41	61
Sulphate radicle (SO_4)	29	15	8.0	8.0	11
Chloride radicle (Cl)	5.1	22	5.0	6.1	17
Nitrate radicle (NO_3)	Trace.	1.7			
Total dissolved solids at 180° C.	101	180	[e] 63	[e] 82	[e] 120
Total hardness as $CaCO_3$	[e] 58	[e] 98	17	28	42
Scale-forming constituents [e]	74	110	40	55	65
Foaming constituents [e]	20	68	20	30	60
Chemical character	Ca-CO_3	Na-CO_3	Na-CO_3	Na-CO_3	Na-CO_3
Probability of corrosion[f]	(?)	N	N	N	N
Quality for boiler use	Good.	Fair.	Good.	Good.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 92-94.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Collected Dec. 1, 1916.
[e] Computed.
[f] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

PUBLIC WATER SUPPLIES.

Separate waterworks are maintained by Norwalk and South Norwalk. The Norwalk system, operated by the incorporated first taxing district, was started in 1872. There are three storage reservoirs on Silvermine River, and a distributing reservoir of 4,500,000 gallons capacity in the city at an elevation of 197 feet above sea level. The lowest of the storage reservoirs, known as the Grupe reservoir, is in the northeast corner of the town of New Canaan. It is formed by a stone dam 250 feet long and 28 feet high, which stores 62,000,000 gallons. Its elevation is 297 feet above sea level. The Brown reservoir, a quarter of a mile north of the New York State line, has a capacity of 201,000,000 gallons. The dam is of the core-wall type, 1,300 feet long, 43 feet high, and has a spillway elevation of 420 feet above sea level. The Scott reservoir, 1½ miles north of the State line, with its spillway 500 feet above sea level, has a capacity of 58,000,000 gallons. The dam of this reservoir is 150 feet long and 25 feet high and is built of stone. The water is distributed by gravity through 44 miles of mains to 229 hydrants and 2,250 service taps. The pressure is from 60 to 80 pounds to the square inch. The consumption is said by the commissioners to average 2,500,000 gallons a day. It is said that weir measurement, the records of which have been lost, indicated an average discharge of 10,000,000 gallons a day for Silvermine River. The area of the tributary drainage basin is about 10 square miles. The water is treated in a liquid chlorine purification plant at the Grupe reservoir.[1]

The South Norwalk waterworks,[2] which also serve East Norwalk, are operated by the second taxing district of the city. Construction was begun in 1875, and later in that year service was commenced. About 189 mains were laid across the river to East Norwalk. There are at present four reservoirs and a fifth is planned. All are in the town of Wilton.

Silvermine reservoir (No. 1) is on a small tributary of Silvermine River, near the southwest corner of Wilton. The overflow is at an elevation of 223 feet above sea level. It has an area of 9 acres and a capacity of 12,000,000 gallons. This reservoir is no longer in use except in emergencies, as it is below the level of the filtration plant. A mile farther up the same stream is the dam of the Wilton reservoir (No. 2) with its spillway 266 feet above sea level. This reservoir has an area of 135 acres and a capacity of 500,000,000 gallons and is

[1] Oral communication from commissioners.

[2] Second Taxing District of the City of Norwalk Sixth Ann. Rept., 1919.

the largest of the system. Near its lower end it is crossed by a gravel causeway which effects a partial filtration of the water. A short distance above the Wilton reservoir is the Huckleberry reservoir (No. 3). It has an area of 29 acres and a capacity of 162,904,000 gallons, and its spillway is 327 feet above sea level.

On a stream flowing through North Wilton and about midway between North Wilton and Wilton is the North Wilton reservoir (No. 4). It covers only 3 acres and has a capacity of only 2,000,000 gallons. This reservoir is used merely to divert water to the Wilton reservoir to which it is connected by a large pipe line. Its spillway is 302 feet above sea level. A fifth reservoir is planned on this stream. It will have a capacity of 800,000,000 gallons, an area of 110 acres, and a spillway elevation of 400 feet above sea level.

Just below the Wilton reservoir is a double sand filtration plant built to eliminate objectionable odor-producing and taste-producing organisms. The primary filter consists of five roofed concrete compartments, each covering about 11,000 square feet. At the bottom are lateral lines of 10-inch split vitrified tile tributary to a large central effluent channel. The underdrains are covered with 18 inches of graded gravel, above which is 3 feet 9 inches of sand with an effective size of 0.35 to 0.38 millimeter. Before entering the primary filters the water is aerated by running it through a steel box 9 feet 3 inches long by 6 feet 6 inches wide and 4 feet deep, in the bottom of which are 6,836 holes three-sixteenths of an inch in diameter. In a drop of about 3½ feet the streams of water twist and break and the water becomes thoroughly aerated.

From the primary filter the water passes through Venturi meters, one for each bed, which record the rate of filtration. The water is then run through a secondary aeration box and a secondary filter. The construction of these is the same as in the primary set, except that there is only one filter bed. The primary filtration effectually eliminates the organic matter, and the secondary filtration the objectionable mineral matter (iron and manganese). The daily average of the primary filters was 2,540,233 gallons for the year ending May 1, 1919. The beds were run 18 days on the average between cleanings, but the time varied with the season of the year from 9 to 51 days. The secondary filter was run at a rate about four times as high and with a longer interval between cleanings.

The water is distributed by gravity through 49 miles of main pipe to 266 hydrants and 2,874 house taps. The domestic consumption is about 130 gallons per capita per day, but this is increased by the consumption in factories, hotels, and other establishments to about 190 gallons a day. This consumption is excessive, and the

water used by the 14,000 consumers could by metering be made to suffice for 20,000 people. The projected reservoir, the site and rights for which have already been procured, will provide water enough for a population of 60,000.

RECORDS OF WELLS.

Wells dug in till in Norwalk.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Plain......	140	27.8	25.8	2.0	Windlass rig......	Nonfailing.
2	....	Slope......	120	27.1	25.7	1.4	Two-bucket rig...	Do.
3	....	Plateau....	125	28.1	26.9	1.2	Windlass rig......	
4	....	Slope......	120	18.4	15.1	3.3	Chain pump......	Do.
5	W. S. Stewart...	Knoll......	175	28.1	24.4	3.7	Windlass rig......	Do.
7	....	Slope......	190	15.7	9.6	6.1	Air-pressure system.	Do.
8	....	.....do.....	145	24.4	18.0	6.4	Windlass rig......	Do.
9	....	Plateau....	205	11.5	8.9	2.6	Windlass rig and house pump.	Do.
10	....	Slope......	255	16.0	14.3	1.7	Windlass rig......	
11	....	.....do.....	230	25.0	17.0	8.0	Chain pump and electric pump.	Do.
12	....	.....do.....	230	18.0	15.2	2.8	Windlass rig......	
13	....	.....do.....	240	30.0	27.0	3.0	Deep-well pump and hot-air engine.	Do.
14	....	.....do.....	225	24.7	19.6	5.1	Windlass rig......	Fails.
15	....	.....do.....	117	14.5	13.6	0.9	Two-bucket rig...	Do.
16	....	.....do.....	175	25.1	19.1	6.0	Windlass rig......	Do.
17	....	.....do.....	145	21.7	....	Dry.	.....do...........	Fails. Rock bottom.
18	....	.....do.....	125	16.8	14.4	2.4	Two-bucket rig...	Nonfailing.
19	....	.....do.....	110	11.9	9.9	2.0	Sweep rig.........	Do.
20	....	.....do.....	120	17.9	16.5	1.4	Windlass rig......	Fails.
21	....	.....do.....	195	14.0	8.0	6.0	.....do...........	Nonfailing.
22	....	.....do.....	170	10.9	9.2	1.7	Chain pump......	Do.
25	....	.....do.....	120	19.3	10.6	8.7	.....do...........	Do.
26	....	.....do.....	145	17.9	12.9	5.0	.....do...........	Do.
27	....	.....do.....	170	12.8	9.8	3.0	Two-bucket rig...	Do.
28	....	Plateau....	210	19.0	13.3	5.7	.....do...........	Do.
29	....	.....do.....	165	19.1	18.1	1.0	Windlass rig......	Fails.
31	....	.....do.....	95	17.4	15.6	1.8	Two-bucket rig...	Do.
33	....	.....do.....	125	18.5	15.8	2.7	.....do...........	Do.
38	....	Slope......	150	18.9	12.9	6.0	.....do...........	Nonfailing.
39	....	Plateau....	175	40.1	29.9	10.2	Gasoline engine...	Do.
40	....	Slope......	150	14.3	10.8	3.5	Two-bucket rig and house pump.	Do.
41	....	.....do.....	180	20.7	17.6	3.1	Two-bucket rig...	Fails. Rock; 5 feet.
42	....	Swale......	170	12.7	10.0	2.7	Chain pump......	Fails. Rock bottom.
43	....	Slope......	105	17.7	16.0	1.7	Two-bucket rig and house pump.	Nonfailing.
44	....	.....do.....	115	20.1	14.6	5.5	Chain pump......	
45	....	.....do.....	140	20.1	13.9	6.2	Two-bucket rig...	Do.
47A	J. R. Connor....	.....do.....	85	28.3	26.1	2.2	Chain pump......	Fails. For analysis see p.89.
51	....	.....do.....	60	19.1	15.2	3.9	Two-bucket rig...	Nonfailing.
52	....	.....do.....	110	18.8	14.5	4.3	.....do...........	
53	....	.....do.....	195	19.4	18.3	1.1	Chain pump......	Fails.
54	....	.....do.....	165	14.8	10.2	4.6	House pump......	Nonfailing.
55	....	Plain......	160	14.2	11.9	2.3	Sweeping and house pump.	Do.
57	....	Ridge......	220	24.3	17.6	6.7	Two-bucket rig and house pump.	Do.
58	....	Slope......	200	31.7	28.8	2.9	Two-bucket rig...	Do.
60	....	.....do.....	175	27.0	......	......	Deep-well pump..	Fails.
60A	....	.....do.....	170	32.0	15.0	17.0	....	Nonfailing.
61	....	.....do.....	150	12.1	8.8	3.3	Sweep rig.........	Do.

Wells dug in till in Norwalk—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
62		Plain	125	15.1	12.7	2.4	Chain pump	Nonfailing.
64		Slope	115	15.7	14.3	1.4	....do	Do.
65		Plain	120	11.5	9.1	2.4	Sweep rig	Do.
68		....do	210	15.5	10.1	5.4	Windlass rig	
71		Slope	65	19.5	13.8	5.7	....do	Do.
76	Stephen Fiore	Hill	105	24.1	16.1	8.0	Two-bucket rig and house pump.	Do.
77		Slope	100	18.9	16.1	2.8	Two-bucket rig	Do.
78		....do	65	17.1	16.0	1.1	....do	Fails.
79		....do	40	18.4	15.8	2.6	Windlass rig	
80		....do	65	27.5	23.7	3.8	Two-bucket rig	
82		....do	90	10.8	5.3	5.5	House pump	Nonfailing.
84		....do	60	23.0	18.3	4.7	Two-bucket rig	Do.
85		Swale	70	8.1	6.0	2.4	No rig	Fails.
86		Slope	55	9.8	7.7	2.1	Two-bucket rig	Do.
90		Hill	[illegible]	18.7	15.0	3.7	....do	Do.
91		Slope	20	9.5	5.4	4.1	Chain pump	Nonfailing.
92		....do	75	22.0	14.5	7.5	Two-bucket rig	
93		Hilltop	40	31.7	17.9	13.8	Windmill	Do.
95		Plain	10					Never used; water salty.
96		Slope	40	10.3	6.8	3.5	Chain pump	Nonfailing.
98		....do	85	17.6	11.5	6.1	Two-bucket rig	Do.
99		....do	75	14.6	13.5	1.1	Windlass rig	
101		Plateau	130	19.6	13.3	6.3	Two-bucket rig	Do.
103		Island (?)						

Wells dug in stratified drift in Norwalk.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
23		Slope	115	11.0	8.2	2.8	Windlass rig	
24		Plain	90	22.3	19.4	2.9	....do	
30		Slope	75	22.3	19.1	3.2	....do	Nonfailing.
32		....do	90	20.8	18.6	2.2	....do	Do.
34		....do	60	27.1	25.4	2.0	Two-bucket rig	Do.
35		....do	50	15.3	13.6	1.7	....do	Do.
36	Miss M. A. McCarthy.	Plain	70	20.7	18.2	2.5	....do	Fails. For assay, see p. 89.
37		....do	50	27.3	25.0	2.3	....do	
48		....do	35	10.5	6.7	3.8	Chain pump	Nonfailing.
56		....do	130	21.8	19.1	2.7	Windlass rig	Do.
63	Clover Manufacturing Co.	....do	125	22	18	4		Nonfailing; will yield 50 gallons a minute. For assay see p. 89.
66		Slope	120	12.8	11.8	1.0	Chain pump	Fails.
67		....do	110	16.9	15.7	1.2	....do	Nonfailing.
69		Plain	25	11.6	10.0	1.6	....do	Do.
72		....do	70	22.0	19.3	2.7	Tw -bucket rig	Do.
72A		....do	70	21.0	19.4	1.6	....do	Do.
73		....do	75	22.1	18.2	3.9	....do	Do.
74		....do	60	15.7	13.9	1.8	Chain pump	Do.
75		Swale	50	7.7	5.3	2.4	Two-bucket rig.	
87		Plain	30	29.0	26.6	2.4	....do	Do.
88		Terrace	25	21.3	21.5	2.8	....do	Do.
89		Slope	25	20.9	17.7	3.2	Windlass rig	Do.
94	J. W. Marvin	Terrace	10	8.4	6.8	1.6	House pump	Nonfailing; fresh water. For assay see p. 89.

Drilled wells in Norwalk.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water in well.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*In.*	*Gals.*	
6	Fathers of the Holy Ghost.	Slope...	......	136	12	10	6	20	At college building.
6A	....do....	...do....	......	108	20	20	6	5	At farmhouse.
46	Norwalk Iron Works Co.	Valley..	5	260	80	6	8	......	Water hard.
47	J. R. Connor..........	Slope...	85	197	30	......	6	4	Water from gneiss. For analysis see p. 89.
49	Samuel R. Weed.....	...do....	60	45	20	15	6	8	
50	School............	...do....	40	168	16	......	6	½	
59	H. A. Beach........	...do....	210	......	......	......	......	......	
70	Meeker's Union Foundry Co.	Valley.	4	107	......	5	6	......	
81	Town farm..........	Slope...	110	152	40	18	......	......	
83	St. James' Homes....	...do....	110	......	......	......	......	......	
97	Mrs. R. L. Luckey ...	Ridge..	30	188	25	20	6	3	
100	Manresi Institute.....	Island..	8	125	......	8	......	20	Water salty.[a]
102	South Norwalk Oyster Farms Co.	Plain...	5	258	75	......	......	Large	
([b])	Jos. Burns..........	Valley.	......	247	......	10	6	25	Water salty.

[a] For analysis see U. S. Geol. Survey Water-Supply Paper 102, p. 142, 1904.
[b] Not plotted on map. Data from U. S. Geol. Survey Water-Supply Paper 232, p. 82, 1909.

RIDGEFIELD.

AREA, POPULATION, AND INDUSTRIES.

Ridgefield, a town typical of the western highlands of Connecticut, is near the middle of the west boundary of Fairfield County. Danbury adjoins it on the north and Norwalk is 15 miles south on Long Island Sound. To the west is part of Westchester County, N. Y. The town has an area of 35½ square miles. There are several extensive stretches of woodland and many small wood lots. These woods are uniformly distributed over the town on the hills and steeper slopes and aggregate 14 square miles or 40 per cent of the total area. The valleys are for the most part cleared.

Ridgefield was incorporated in 1709, and in 1901 the village was made a borough. There have been no additions to or cessions of the original territory. In 1910 the population was 3,118, an increase of 492 over the 1900 population. The density of population averages 88 to the square mile. The following table shows the population at each census and the per cent change in the preceding interval:

Population of Ridgefield, 1756–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1756	1,115	......	1840	2,474	+ 7
1774	1,708	+53	1850	2,237	−10
1782	1,697	− 1	1860	2,213	− 1
1790	1,947	+15	1870	1,919	−13
1800	2,025	+ 4	1880	2,028	+ 6
1810	2,103	+ 4	1890	2,235	+10
1820	2,301	+ 9	1900	2,626	+17
1830	2,305	0	1910	3,118	+19

[a] Connecticut Register and Manual, 1919, p. 640.

There was in general a moderate growth up to 1840, a marked decrease from 1840 to 1870, and a rapid growth from 1870 to the present time. The decrease was due to the general emigration from the agricultural districts of New England but may have been accentuated by the distance of the town from the first railroads. The subsequent growth is the result of the completion of the railroad in 1870 and of the development of the region as a district of country residences. This development will probably continue and will be greatly stimulated if a projected railroad to connect with the main line of the New York, New Haven & Hartford Railroad at Greenwich is eventually constructed.

The principal settlement is the centrally located borough of Ridgefield. There is also a small settlement, Titicus, a mile northwest of the borough. Branchville is in part in the southeast corner of Ridgefield but spreads over into Redding and Wilton. Ridgebury is a small village in the north part of the town. There is a post office at Ridgefield and rural-delivery service to the outlying sections. There is also a post office at Branchville in Redding. The Danbury branch of the New York, New Haven & Hartford Railroad, opened in 1852, runs north and south along the east boundary and has stations at Branchville and Sanford. The Ridgefield branch, a little less than 4 miles long, connects Ridgefield and Branchville, and has stations at Florida and Cooper. An automobile stage line connects Ridgefield with Danbury.

The principal industry of Ridgefield is agriculture, and dairy products for the New York market form a specialty. The quarrying and grinding of feldspar and quartz have been carried on intermittently. Formerly there was also some manufacturing of cabinet work, shoes, hats, and tinware, but these industries died out about 1850 with the general change of industrial conditions.

SURFACE FEATURES.

The characteristic features of the western highlands of Connecticut are better developed in Ridgefield than elsewhere in the Norwalk area, because it is the most remote from the Sound. In the south part of the town the broad, flat-topped hills are approximately 800 feet above sea level. Farther north the hilltops are approximately 1,000 feet, but in the extreme north part of the town the hills are somewhat lower. The valleys between the hills are cut to different depths. It seems probable that this region was once eroded to a nearly flat surface. Subsequent uplift of the region rejuvenated the streams so that valleys have been cut below the old erosion surfaces. The valley north of Round Mountain and the valley of Titicus River, which join just north of the village of Ridgefield,

and their southwestward continuation are underlain by limestone, which is relatively soluble, so that these zones have been deeply eroded. These valleys are characterized by wide and nearly level floors above which rise steep walls with many bare outcropping ledges. The other valleys have only narrow valley floors. The valley south of Round Pond is also of the broad-floored type and is underlain by limestone. Figure 15 shows a profile across Ridgefield drawn along a line bearing northeast which is indicated on the maps (Pls. II and III) by the line C'. It shows the two limestone valleys cut below the upland areas of gneiss.

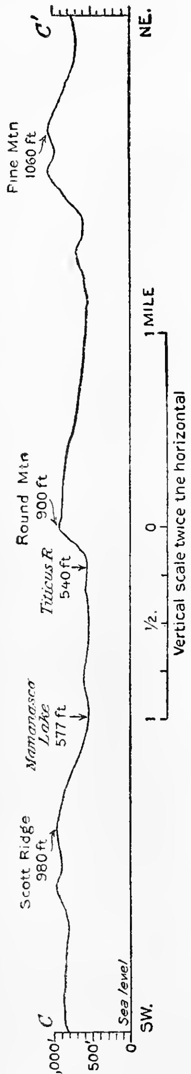


FIGURE 15.—Profile across Ridgefield (section C' on Pls. II and III).

The highest point in Ridgefield is Pine Mountain, the crest of which is 1,060 feet above sea level, and the lowest point is where Norwalk River crosses the south boundary at an elevation of 330 feet.

Mamanasco Lake occupies a depression on the flank of the valley of Titicus River at the foot of the north slope of Scott Ridge. Somewhat similar depressions are to be found elsewhere in the limestone area but have been filled in. Most of the filling was probably done in late glacial times by débris carried by the great volumes of melt water from the glacier. Wells sunk by the Ridgefield Water Supply Co. in the swamp south of Round Pond gave the following section: Alluvium, 40 to 60 feet; clay, 10 feet; sand and gravel, 230 to 250 feet. This section may indicate that the melt water washed in 250 feet of sand, after which the supply of sediment decreased, and the basin became a lake, in the bottom of which 10 feet of clay was deposited. Finally 40 to 60 feet of alluvium has been carried in and the lake filled up. The clay layer must extend under all or nearly all of the swamp, as it effectually prevents any entrance of water into the sands below it.

Ridgefield occupies parts of six drainage basins. An area of about half a square mile in the northwest corner is drained by a small brook tributary to Still River which flows northward and enters Housatonic River near New Milford. The run-off of about 8 square miles in the northeast part of the town reaches Saugatuck River. Ten

square miles in the east-central and southeast parts of Ridgefield are included in the headwaters of Norwalk River. The headwaters of Silvermine River drain about 3 square miles in the southwest part of the town, and just north is an area of 2 square miles tributary to Mill River, which enters Long Island Sound at Stamford. Three square miles at the middle of the western margin of Ridgefield is drained by Waccabuc River, which flows into Cross River and so to Croton River and the Hudson. The west-central and northwest parts of the town are drained by Titicus River, which also is tributary to Croton and Hudson rivers. The borough of Ridgefield, then, includes parts of the basins of Housatonic, Saugatuck, Norwalk, Silvermine, Mill, and Hudson rivers.

WATER-BEARING FORMATIONS.

Bedrock.—Four varieties of bedrock have been recognized in Ridgefield.[1] About 18 square miles in the north part of the town is underlain by the Becket granite gneiss. The original character of this rock is not certain, but it is probably essentially a metamorphic rock of igneous origin. It is a banded gray rock, composed of layers rich in biotite which alternate with layers rich in the lighter-colored quartz and feldspar. The segregation is due to the flowage under intense metamorphism and realinement of the grains under pressure. This structure is more developed in some places than in others, and there makes the rock readily cleavable.

The bedrock of an area of 2 square miles in the southeast corner of the town is the Danbury granodiorite gneiss. It is a gray rock composed substantially of quartz, feldspar, and hornblende. Other minerals are present in minor amounts, and in some phases biotite (black mica) replaces more or less completely the hornblende. In one phase of the rock certain of the feldspar crystals are much larger than the other mineral grains and give the rock a porphyritic texture. The rock is massive but has a distinct gneissoid texture formed by the flowage concomitant with mashing during regional metamorphism.

Underlying an area of 7 square miles in the southwestern part of Ridgefield, and including most of the borough, is the Thomaston granite gneiss. It is similar to the Danbury granodiorite gneiss except that hornblende is nowhere prominent, and the porphyritic texture is absent.

The features of the Becket, Danbury, and Thomaston gneisses that relate to their carrying water are similar, and may be discussed

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Bull. 7, 1907.

together. A little water may be contained in the minute openings between the mineral grains, but its amount is negligible. These rocks have been subjected to great and violent crustal movements which have opened fissures that in general form parallel systems whose directions depend on the direction in which the stresses acted. One system is horizontal or only slightly inclined, and is cut by one or more systems of steeply inclined or nearly vertical fissures. The rock is thus cut into polygonal blocks by the intersecting fissures and joints. Some rain water finds its way through the mantle of overlying unconsolidated material into the intricate network of joints and crevices. Wells drilled into these rocks are apt to intersect, within a reasonable depth, one or more of these water-bearing fissures and thus obtain a moderate to abundant supply of water. Data on five such wells are given in the table on page 103.

The Stockbridge dolomite underlies several valleys half a mile to a mile wide that aggregate 9 square miles in area. This rock is a light gray magnesian limestone and is no doubt of marine origin. Much of the rock has been metamorphosed to a medium-grained, well-crystallized marble. The calcite and dolomite, of which the rock is essentially composed, yield under metamorphism and recrystallize as roughly equidimensional grains that are unlike the elongated minerals formed from sandstones, shales, or igneous rocks. The resulting texture is more massive. The marble is relatively soluble, so that solution channels are very apt to be made by water circulating along joint planes and bedding planes. Water gets into such channels by percolation from the overlying soil and may in many places be recovered by drilled wells. The well of Mr. S. L. Pierpont and the well at the Town Farm are of this type. Interstitial water plays only a minor part in marbles.

Till.—Overlying the bedrock of Ridgefield is till, except where it is replaced by stratified drift or where ledges crop out. When the glacier overrode New England in the ice age it scraped up the mantle of decayed rock over the fresh, unweathered rock below. It also broke off and ground away a good deal of the firm bedrock. These materials were carried along by the ice sheet in its southerly movement and were eventually deposited as till in part in depressions and in part over the flat surfaces of the bedrock. The till is an intimate and heterogeneous mixture of all this débris. Pebbles and cobbles and even large boulders are embedded in a matrix of the finer materials—sand, silt, clay, and rock flour. The till is very compact because of the great weight of the overlying ice sheet which pressed it down. Part of the water that falls as rain soaks into the ground and percolates downward through it until an impervious

zone is reached or a zone of pervious material completely saturated. Some of the water will get into fissures in the underlying bedrock, some of it will move laterally and eventually be returned to the surface in springs or swamps at a lower elevation, and some may be withdrawn by wells. There are in some places bodies of partly washed and stratified materials in the till, and these greatly further the circulation of water. Wells dug in till will furnish moderate supplies of water that slowly percolates into them. Such a supply is fairly dependable in times of drought unless the well is unfavorably situated, as on a steep slope from which the water may drain away. Wells that intersect rather more porous lenses in the till or that reach the waterbed or saturated zone just above the bedrock are apt to yield the most abundant supplies. During the later part of November, 1916, measurements were made of 57 wells dug in till in Ridgefield. At that time 3 were dry, 13 more were said by the owners to fail, and 32 were said to be nonfailing. The data collected are given in detail in the table on page 102 and are summarized in the following table. The wells that were dry have been neglected in computing the depth to water and the depths of water in the wells.

Summary of wells dug in till in Ridgefield.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	33.0	29.9	12.3
Minimum	9.3	5.9	.4
Average	18.8	14.7	3.5

Stratified drift.—Stratified drift is the mantle rock of a considerable part of the valleys of Ridgefield that are underlain by the Stockbridge dolomite, and of parts of the valley of Norwalk River. It is a well-washed and sorted stratified deposit formed in large part from till by the action of running water. It is an older alluvium and on the map (Pl. III) it is not differentiated from recent alluvium. The only differences are, first, that stratified drift was laid down at the end of the glacial epoch by the streams of melt water that issued from the ice sheet, whereas alluvium is more recent and is still being laid down, and, second, that stratified drift is apt to be but is not necessarily the coarser. Owing to the sorting action of the water the interstices between the larger particles are not filled by smaller particles as in till, so that the porosity is greater. Moreover, the pores individually are larger and present less frictional resistance to the circulation of water. Wells in stratified drift get water in the

same way as wells in till but with greater abundance. Seven such wells were measured in Ridgefield. Two were said to fail, and three to be nonfailing, but the reliability of the other two could not be ascertained. The data collected concerning these wells are given in detail in the table on page 103 and are summarized in the following table:

Summary of wells dug in stratified drift in Ridgefield.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	15.9	13.3	5.5
Minimum	14.0	7.7	.9
Average	14.4	11.8	2.7

QUALITY OF GROUND WATER.

The following table gives the results of two analyses and four assays of samples of ground water collected in the town of Ridgefield. The waters are moderately mineralized except Nos. 15, 72, and 74, which have a low mineral content. Nos. 72 and 74 are very soft, in contrast with No. 15, which is a soft water, and Nos. 16, 48, and 57, which are hard waters. The reason for this contrast is presumably that wells Nos. 72 and 74 lie in situations where the glacier brought no débris derived from the Stockbridge dolomite, whereas the till around the other wells contains a considerable proportion of the relatively soluble dolomitic material. A comparison of analysis No. 15, which represents a sample from a well drilled into the dolomite, with analysis No. 16, which represents a sample from a near-by shallow well dug into the till, also suggests that the ground-up dolomitic material is especially susceptible to solution and tends to make highly mineralized waters. The solid, firm dolomite, on the other hand, is less easily dissolved, by reason of its mechanical condition and therefore yields less highly mineralized waters.

The waters represented by analyses Nos. 15, 72, and 74 are good for domestic purposes so far as may be judged from their mineral content, but the other waters are rated as fair because of their hardness. Nos. 15, 72, and 74 are also acceptable for boiler use, but the other waters are rated as poor because of excessive amounts of scale-forming ingredients. All are calcium-carbonate in type except the very soft waters, Nos. 72 and 74, which are sodium-carbonate waters.

Chemical composition and classification of ground waters in Ridgefield.[a]

[Parts per million; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. II.]

	Analyses.[b]		Assays.[c]			
	[d]15	[d]16	[e]18	[e]57	[e]72	[e]74
Silica (SiO_2)	17	18	....	....	....	....
Iron (Fe)	.14	.40	0.13	0.22	Trace.	0.09
Calcium (Ca)	18	57	....	....	....	....
Magnesium (Mg)	4.6	17	....	....	....	....
Sodium (Na)	11	12	Trace.	[f]22	[f]11	[f]10
Potassium (K)	6.9	6.4				
Carbonate radicle (CO_3)	.0	7.0	7.2	4.8	.0	.0
Bicarbonate radicle (HCO_3)	77	230	251	334	62	34
Sulphate radicle (SO_4)	14	22	11	27	6.0	9.0
Chloride radicle (Cl)	6.2	6.8	3.6	14	2.2	3.2
Nitrate radicle (NO_3)	.08	4.1	....	....	....	....
Total dissolved solids at 180° C	114	253	[f]280	[f]380	[f]91	[f]73
Total hardness as $CaCO_3$	[f]64	[f]212	244	285	33	22
Scale-forming constituents [f]	78	210	270	310	60	45
Foaming constituents [f]	49	49	(*g*)	60	40	30
Chemical character	Ca-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3	Na-CO_3	Na-CO_3
Probability of corrosion [h]	(?)	(?)	(?)	(?)	N	N
Quality for boiler use	Good.	Poor.	Poor.	Poor.	Good.	Good.
Quality for domestic use	Good.	Fair.	Fair.	Fair.	Good.	Good.

[a] For location and other descriptive information see pp. 102-103.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Collected Nov. 28, 1916.
[e] Collected Dec. 8, 1916.
[f] Computed.
[g] Less than 10 parts per million.
[h] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

PUBLIC WATER SUPPLY.

The Ridgefield Water Supply Co. has been serving its customers in and around the borough since 1900. Water was first obtained from five driven wells in a swamp a mile south-southwest of Round Pond. These wells were 60 feet deep; two were 6 inches and three were 3 inches in diameter. They drew moderate amounts of water from gravel, but the water was under very slight head and had to be lifted 50 feet. Subsequently three wells were sunk at the same place to depths of about 300 feet. They went through 40 to 50 feet of alluvium, 10 feet or so of clay, and finally through more than 200 feet of sand. No water was obtained below the clay and only moderate amounts above it.

At present all the wells are abandoned and water is pumped from Round Pond to a steel standpipe of 188,000 gallons capacity located on a ridge 1½ miles south-southeast of the pond. There are two triplex single-acting pumps, 10 by 10 inches, driven by two 35-horsepower electric motors and working against a pressure of 75 pounds to the square inch. The water is distributed by gravity from the standpipe through 11 miles of mains to 70 hydrants and 383 service taps, of which 311 are metered. The pressure ranges from 75 to 90 pounds per square inch. The 2,500 people served consume on the average about 148,000 gallons a day. Round Pond is presumably

fed by subaqueous springs.[1] The water in the pond has heretofore been abundant, and a much larger quantity could be furnished.

RECORDS OF WELLS AND SPRINGS.

Wells dug in till in Ridgefield.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth	Depth to water.	Depth of water.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
2	....	Slope	620	9.4	5.9	3.5	Chain pump......	Nonfailing.
3	....	.....do......	560	18.5	14.2	4.3	Chain pump and house pump.	Do.
4	....	.....do......	500	12.7	7.7	5.0	Chain pump......	Do.
5	....	.....do......	560	17.9	11.1	6.8	.....do............	Do.
6	....	Hill........	610	21.6	14.8	6.8	.....do............	Do.
7	....	Slope.......	685	19.2	13.8	5.4	Two-bucket rig....	
8	....	.....do......	785	30	......	Dry	Deep-well pump..	Fails.
9	....	Hill........	665	25.2	......	Dry	Windlass rig......	Do.
10	....	Slope.......	795	13.4	12.2	1.2	No rig............	Do.
12	....	.....do......	570	12.3	......	Dry	Two-bucket rig....	Do.
13	....	.....do......	620	22.9	20.7	2.2	Chain pump......	Nonfailing.
16	S. L. Pierpont....	.....do......	540	15.4	13.3	2.1	House pump......	Nonfailing. For analysis see p. 101.
17	....	.....do......	565	24.6	23.5	1.1	Two-bucket rig....	Do.
19	....	.....do......	650	25.7	24.4	1.3	.....do............	Fails.
20	....	.....do......	605	13.5	11.2	2.3	Chain pump......	
22	....	.....do......	595	16.6	13.9	2.7	.....do............	Nonfailing.
24	....	.....do......	695	23.3	19.8	3.5	.....do............	Nonfailing. Rock bottom.
25	....	.....do......	610	21.2	19.0	2.2	Two-bucket rig....	Do.
26	....	.....do......	780	25.7	24.4	1.3	.....do............	
27	....	.....do......	590	24.6	16.0	8.6	Sweep rig.........	Do.
29	....	Ridge......	825	21.0	19.6	1.4	Two-bucket rig....	Fails.
30	....	Slope.......	730	22.0	21.7	0.3	Windlass rig......	Fails. Rock bottom.
31	....	Swale......	715	24.0	20.5	3.5	.....do............	Nonfailing.
33	....	Slope.......	630	10.1	9.6	0.5	Chain pump......	Fails.
34	....	.....do......	700	19.9	17.4	2.5	Two-bucket rig....	Nonfailing.
35	....	.....do......	670	13.5	12.0	1.5	Chain pump......	Fails.
36	....	.....do......	720	17.0	16.6	0.4	Two-bucket rig....	Do.
39	....	.....do......	670	9.3	6.0	3.3	Windlass rig......	Nonfailing.
42	....	.....do......	765	16.4	8.9	7.5	Chain pump......	Fails.
43	....	.....do......	745	20.8	15.0	5.8	.....do............	
44	....	.....do......	790	11.6	9.7	1.9	Sweep rig.........	Nonfailing.
45	....	.....do......	575	14.9	14.0	0.9	Two-bucket rig....	Fails.
46	L. D. Conley.....	Plain.......	470	18	3	15	....	Nonfailing.
47	....	Slope.......	550	30.6	29.9	0.7	Two-bucket rig....	Fails.
48	John H. Finch...	.....do......	575	33.0	29.8	3.2	.....do............	Nonfailing. For assay see p. 101.
49	....	.....do......	590	17.1	15.5	1.6	.....do............	Fails.
50	....	.....do......	600	14.8	12.4	2.4	Chain pump......	Do.
51	....	.....do......	635	9.3	7.0	2.3	.....do............	Nonfailing.
52	....	.....do......	750	25.2	19.4	5.8	.....do............	Fails.
54	Lawrason Riggs..	Ridge......	755	18.9	13.3	5.6	.....do............	Nonfailing.
55	The Bailey Inn...	Plateau....	770	19.7	11.7	8.0	.....do............	Do.
56	....	.....do......	790	9.6	8.0	1.6	Sweep rig and house pump.	Nonfailing. Abandoned.
57	E. S. Couch......	.....do......	740	25.6	13.3	12.3	Chain pump......	Nonfailing. For assay see p. 101.
58	....	.....do......	785	14.4	10.3	4.1	House pump......	Nonfailing. Rock bottom.
59	....	Slope.......	780	20.8	12.5	8.3	Two-bucket rig....	Do.
60	....	Ridge......	765	25.9	23.5	2.4	.....do............	
61	....	Plateau....	745	20.5	13.6	6.9	.....do............	Do.
62	....	Slope.......	615	16.6	13.3	3.3	Wheel and axle rig.	Do.
63	....	.....do......	630	25.6	15.5	10.1	Wheel and axle rig and house pump.	Do.
64	....	.....do......	705	15.0	13.6	1.4	Two-bucket rig....	Do.
65	....	.....do......	525	17.3	14.7	2.6	.....do............	
66	....	.....do......	640	18.2	12.9	5.3	Chain pump......	Nonfailing.
67	....	.....do......	690	14.0	12.9	1.1	Windlass rig......	Do.
68	....	.....do......	500	13.2	10.6	2.6	No rig............	
71	....	Slope.......	550	13.2	12.1	1.1	Chain pump......	
72	George A. Knox..	Knoll......	436	14.6	12.7	1.9	Sweep rig and house pump.	Nonfailing. For assay see p. 101.
73	....	Slope.......	450	24.9	24.5	0.4	Wheel and axle rig.	

[1] Rept. Connecticut Public Utilities Commission, 1917.

Wells dug in stratified drift in Ridgefield.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
21	....	Slope......	575	14.4	13.0	1.4	Two-bucket rig....	Fails.
37	....	.....do.....	640	14.8	13.1	1.7	Windlass rig.......	Do.
38	....	.....do.....	650	14.2	13.3	0.9	Two-bucket rig....	
46	L. D. Conley.	Plain.......	470	18	3	15	(*a*)	Nonfailing.
69	....	Slope......	455	15.9	11.8	4.1	Chain pump.......	
70	....	Plain.......	445	13.2	7.7	5.5	Windlass rig.......	Do.
74	Seth Beers..	Slope.......	330	14.0	11.6	2.4	Two-bucket rig.....	Nonfailing. For assay see p. 101.

a This well was originally a spring and was improved by means of a drive pipe. Yields 1,500 gallons an hour or 25 gallons a minute.

Drilled wells in Ridgefield.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water in well.	Diameter.	Yield per minute.	Kind of rock.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*In.*	*Gals.*		
1	Ben Nichols.......	Slope....	590	105	9	13	6	15	Gneiss.......	Bored well.
14	Ridgefield School.	...do.....	720	210	......	......	6	(*a*)	.....do........	Do.
15	S. L. Pierpont....	...do.....	560	389¾	0	3	6	30	Limestone....	Bored well. For analysis see p. 101.[b]
18	Town farm........	...do.....	640	450	......	......	......	......	.....do........	Water very hard.
28	Ridgefield Water Supply Co.	Plain....	530	300	300+	......	......	0	(*c*)	Abandoned.
40	A. B. Hepburn....	Plateau.	800	537	40	25	8	50	Granite gneiss.	(*d*)
41	Mrs. Wm. Jenner.	...do.....	800	551	40	25	8	50	.....do........	(*d*)
53	Lawrason Riggs..	...do.....	720	630	0	(*e*)	8	(*a*)	.....do........	
(*f*)	Connecticut Construction Co.	....	......	75	......	......	......	......	....	

a Abundant.

b A number of zones of dark limestone were found in the light-colored limestone. Each of these beds yielded some water.

c Three wells, each about 300 feet deep, were attempted. The section encountered was in general 40 to 60 feet of alluvium, 10 feet of clay, and the rest sand. No water was found beneath the clay.

d These wells, Nos. 40 and 41, probably draw their water from the same fissure as pumping in one draws down the level of the water in the other.

e The water stands at from 130 to 250 feet below the surface and varies with the seasons.

f Not recorded on map. Data from U. S. Geol. Survey Water-Supply Paper 102, p. 128, 1904, said to flow with head of 2 feet.

Springs in Ridgefield.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
			Feet.	*°F.*	*Gallons.*	
11	....	Slope......	620	....	½	Piped to horse trough.
23	....	Swale......	635	....	2	Supplies four houses.
32	....	Brookside..	650	49	½	
(*a*)	R. A. Bryan.......	....	....	40	5	Water from granite.
(*a*)	Chas. Holly........	....	....	48	....	Water from granite.[b]

a Not shown on map. Data from U. S. Geol. Survey Water-Supply Paper 102, p. 150, 1904.

b For analysis see U. S. Geol. Survey Water-Supply Paper 102, p. 154, 1904.

WESTON.

AREA, POPULATION, AND INDUSTRIES.

Weston is an agricultural town situated in the western highlands near the center of Fairfield County, Conn., and in the second tier of towns north of Long Island Sound. The town is roughly rectangular in shape, 3½ by 6 miles in dimensions, and has an area of a little over 20 square miles. About 11 square miles, or 55 per cent, of the total area is wooded. Most of the woodland is in small patches, but in the northeastern part of the town there is one nearly continuous area of woods covering about 8 square miles.

The territory of Weston was taken from the town of Fairfield in 1787 and incorporated as a separate town. In 1910 Weston had 831 inhabitants, and the density of the population is 42 to the square mile. The following table shows the fluctuation of population since the organization of the town, and the per cent of change of each census period.

Population of Weston, 1790–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1790	2,469		1860	1,117	+6
1800	2,680	+9	1870	1,054	−6
1810	2,618	−2	1880	918	−13
1820	2,767	+6	1890	772	−16
1830	2,997	+8	1900	840	+9
1840	2,561		1910	831	−1
1850	1,056				

[a] Connecticut Register and Manual, 1919, p. 641.

The decrease in the decade from 1830 to 1840 was due to the cession of territory to form part of Westport, and the further decrease in the following decade was due to the separation and incorporation of the whole of Easton. Barring these two irregularities, the population has shown only slight gains or losses. In the last 50 years the losses have preponderated, probably owing to the general shift of people from the agricultural portions of New England to manufacturing towns and to western farming regions. It is probable that when Wilton and Westport have been more fully developed as country-residence districts dependent on New York, Weston will follow a like course of evolution. This development may begin in 10 or 15 years, and a considerable gain in population may be shown for some time. The population will probably never be large as long as the present lack of transportation facilities continues. At present there are four small villages in the town—Weston, in the valley of the West Branch of Saugatuck River near the west boundary; Northfield, on the hill a mile east of Weston; Lyon Plain, stretched

out along 2 miles of the valley of Saugatuck River near the south boundary; and Valley Forge, near the northeast corner and also on Saugatuck River. There are about 70 miles of roads in the town. Railroad connection is made at Wilton and Georgetown on the Danbury branch of the New York, New Haven & Hartford Railroad. Mail is carried by rural delivery from Westport.

SURFACE FEATURES.

The western highland of Connecticut, of which Weston is a part, is the product of two cycles of erosion. In the first cycle, which was nearly complete, the region was reduced to a nearly flat plain. In the second cycle, caused by uplift and tilting of the plain, rather deep and narrow valleys have been cut below the old erosion surface. The valleys of Saugatuck River and its West Branch and of Aspetuck River are of this type. The flat-topped hills, which in the south part of the town are 340 to 380 feet above sea level and in the north part 500 to 600 feet above sea level, are remnants of the plain that was eroded in the first cycle. These topographic features are the products of erosion, but the flat flood plains along Saugatuck River at Lyon Plain and above Valley Forge and along West Branch north of Weston village are depositional features.

The greatest elevation in Weston is 620 feet above sea level and is found at two points on the north boundary. The least elevation is where Saugatuck River crosses the Westport town line at 45 feet above sea level. With the exception of a small area in the northwest part of the town that is tributary to Norwalk River, all of Weston belongs in the drainage basin of Saugatuck River. A strip three-quarters of a mile wide along the east border is drained by Aspetuck River, which joins Saugatuck River half a mile below the Westport boundary. A strip 2 miles wide in the west part of Weston which comprises 7½ square miles is drained by the West Branch of Saugatuck River, which flows into its master stream just below Aspetuck River. The main branch of Saugatuck River drains a strip 1 to 2 miles wide through the center of the town, which has an area of 10½ square miles. A number of brooks, including Kettle and Beaver brooks, enter the Saugatuck from the west, but only a few from the east.

WATER-BEARING FORMATIONS.

Gneiss and schist.—Most of the bedrock of Weston is a gneiss of igneous origin. In the northeast corner there is some Berkshire schist, but it is of negligible extent. Waterbury gneiss underlies a strip half a mile wide along the divide between Saugatuck River and the Aspetuck. This rock is a light to medium gray schist into

which igneous intrusions have been made in great profusion. There are thin bands of the schist separated and cut by intruded sheets and dikelets of igneous material. The Thomaston granite gneiss underlies a strip half a mile wide south of Aspetuck village along Aspetuck River, and also most of the area west of Saugatuck River. It is a medium-grained granite and a typical one in that it is composed essentially of quartz, feldspar, and black mica, with small amounts of other minerals. Metamorphism has given it a gneissic texture that is marked by the concentration and parallel orientation of the mica flakes in certain planes. The Danbury granodiorite gneiss underlies part of the valley of the West Branch of Saugatuck River and a small area west of Aspetuck River and north of the village of Aspetuck. It is similar to the Thomaston granite gneiss except that hornblende rather extensively replaces the mica.

All the bedrock of Weston carries water in the same way. The rocks are very compact, and no interstitial water is to be obtained from them. However, they are traversed by intricate networks of fissures that cut and connect with one another. These fissures are far more abundant in the upper 200 feet than below. It is to be expected that wells drilled 200 or 300 feet into rock will cut one or more fissures and obtain fair supplies of water that has percolated down from the overlying mantle of earth. No such wells have been made in Weston as far as the present investigation shows.

Till.—The bedrock of Weston is everywhere covered with till except in small areas where the bedrock outcrops in ledges, and along some of the streams where there are deposits of stratified drift. Till is a dense, compact deposit composed of the débris scraped up, ground, and transported by the glacier. Rock flour, clay, silt, and sand form a matrix in which are embedded pebbles, cobbles, and boulders. In general there is no systematic arrangement of the material, and it is perfectly heterogeneous. In some places there are lenses from which the finer particles have been washed away, increasing the porosity of the residue. Water that has fallen as rain or melted from snow in part soaks into the ground and tends to saturate it by filling all the pores. There also is a tendency, particularly on steep slopes, for the water to seep away, leaving the upper part of the till dry. In general wells dug in the till to a reasonable depth will yield moderate supplies that will fail only rarely. Those wells that intersect porous lenses in the till are apt to be the more satisfactory. Unfortunately there is no way of detecting the presence of such lenses except by actual excavation. During October, 1917, 33 wells dug in till were measured in Weston. One was found to be dry, 11 more were said to fail, and 18 to be nonfailing; the reliability of the remaining wells could not be ascertained. The data collected are given in detail in the table on pages 108–109 and are summarized in the following table:

Summary of wells dug in till in Weston.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	28.7	23.8	8.6
Minimum	8.9	6.2	.3
Average	17.7	14.4	3.0

Stratified drift.—The areas of stratified drift in Weston are shown on the map (Pl. II). These water-laid deposits are composed of the reworked and sorted constituents of the till and are to be considered as the products of the stream in whose valley they lie. The particles composing the till have been sorted out. The boulders and bigger stones have been left in place, but the sand and still finer grains have been carried away. Most of the finest materials, the clay and silt, have been carried out to sea, but the others have been deposited at points where the current was slow. The larger pebbles and cobbles were deposited with less slowing of the current than were the smaller ones. Inasmuch as the velocity varied not only from place to place but also from time to time at any one place, lenses and beds of different-sized material were laid one on another in very irregular succession. Stratified drift carries water in the same manner as till, but because of the elimination of the smaller particles it has a greater percentage of pore space and the pores are larger. The ground-water circulation is therefore much more rapid, and stratified drift wells yield more abundant supplies. Six such wells were visited in Weston. Five of them are said to be nonfailing and only one to fail. The data collected are given in detail in the table on page 109 and are summarized in the following table:

Summary of wells dug in stratified drift in Weston.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	33.7	30.7	3.0
Minimum	15.6	13.7	0.3
Average	25.1	23.4	1.7

QUALITY OF GROUND WATER.

The subjoined table gives the results of two analyses and four assays of samples of ground water collected in the town of Weston. The waters are all low in mineral content, very soft, good for use in boilers, and, so far as may be determined by their mineral content, acceptable for domestic use. All are sodium-carbonate in type.

Chemical composition and classification of ground waters in Weston.[a]

[Parts per million. Collected Dec. 8, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. II.]

	Analyses.[b]		Assays.[c]			
	18	27	22	30	34	38
Silica (SiO_2)	17	25	......	......	......	......
Iron (Fe)	Trace.	.18	0.14	0.10	Trace.	Trace.
Calcium (Ca)	6.6	3.9	......	......	......	......
Magnesium (Mg)	2.0	2.0	......	......	......	......
Sodium and potassium (Na+K)[d]	9.8	14	12	9	9	10
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	28	30	38	29	34	32
Sulphate radicle (SO_4)	15	6.6	6.0	6.0	6.0	7.0
Chloride radicle (Cl)	2.3	12	2.6	3.4	3.0	2.8
Nitrate radicle (NO_3)	5.0	.18	......	......	......	......
Total dissolved solids at 180° C	75	67	[d] 71	[d] 64	[d] 68	[d] 67
Total hardness as $CaCO_3$	[d] 25	[d] 18	18	16	20	18
Scale-forming constituents[d]	40	40	45	40	45	45
Foaming constituents[d]	26	38	30	20	20	30
Chemical character	Na-CO_3	Na-CO_3	Na-CO_3	Na-CO_3	Na-CO_3	Na-CO_3
Probability of corrosion[e]	(?)	N	N	N	N	N
Quality for boiler use	Good.	Good.	Good.	Good.	Good.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 108–109.
[b] For methods used in analyses and accuracy of results see pp. 52–60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52–60.
[d] Computed.
[e] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

RECORDS OF WELLS AND SPRINGS.

Only one spring (No. 11, Pl. II) was visited in Weston. It is on a hillside and its water is piped by gravity to the house below.

Wells dug in till in Weston.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	......	Slope	360	8.9	6.9	2.0	Chain pump	Fails.
2	......	do	390	22.5	21.8	0.7	do	Do.
3	......	do	340	22.6	18.9	3.7	Windlass rig	Nonfailing.
4	......	do	370	24.8	......	Dry.	Two-bucket rig	Fails.
5	......	do	425	15.3	14.4	0.9	do	Do.
6	......	do	310	22.5	21.7	0.8	do	Do.
7	......	do	315	16.6	14.8	1.8	do	Nonfailing.
8	......	do	270	11.7	9.0	2.7	do	Do.
9	......	do	330	11.6	7.4	4.2	do	Do.
10	......	do	400	10.9	6.2	4.7	do	Fails.
12	......	do	380	28.2	23.2	5.0	Windlass rig	Do.
14	......	do	425	21.5	18.4	3.1	Chain pump	Do.
15	......	do	425	13.7	11.2	2.5	Sweep rig	
16	......	do	350	15.6	15.3	0.3	Two bucket rig	Do.
17	......	do	250	13.8	12.0	1.8	do	Nonfailing.
18	Lafayette Beers	do	215	11.5	7.9	3.6	Sweep rig	Nonfailing. For analysis see p. 108.
19	......	do	315	11.6	9.7	1.9	Windlass rig	Fails.
20	F. W. Hawly	do	155	16.3	14.6	1.7	House pump and two-bucket rig.	Nonfailing.
21	......	Swale	295	11.8	7.7	4.1	do	Do.
22	Mary L. Fanton	Plain	190	17.2	14.9	2.3	Two-bucket rig.	Nonfailing. For assay see p. 108.
23	......	Knoll	300	18.4	15.1	3.3	House pump and windlass rig.	Nonfailing.
24	......	Slope	420	21.0	16.4	4.6	Windlass and counterbalance rig.	Do.
26	......	Hilltop	360	28.7	23.8	4.9	do	Fails.
27	John R. Cole	Slope	315	17.7	12.3	5.4	do	Nonfailing. For analysis see p. 108.

Wells dug in till in Weston—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
28	....	.....do......	325	21.0	16.7	4.3	Two-bucket rig..	
29	....	.....do......	315	21.0	17.7	3.3	Wheel and axle rig.	Nonfailing.
30	Mrs. Sutton....	.....do......	190	17.5	16.3	1.2	Two-bucket rig..	Fails. For assay see p. 108.
31	....	Plateau....	280	20.8	12.8	8.0	.....do...........	Nonfailing.
34	G. Jacobi......	Slope.......	100	16.4	12.8	3.6	Deep-well pump and house pump	Nonfailing. For assay see p. 108.
35	....	.....do......	225	15.4	12.6	2.8	One-bucket rig..	Nonfailing.
36	....	.....do......	230	14.5	10.3	4.2	Two-bucket rig..	Do.
37	....	.....do......	110	24.8	23.8	1.0	Windlass rig....	Do.

Wells dug in stratified drift in Weston.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
13	....	Slope........	180	15.6	13.7	1.9	Two-bucket rig.	Nonfailing.
25	....	Plain........	180	31.0	30.7	.3	Windlass rig....	Fails.
32	....	Slope........	80	2,817	25.8	2.9	Two-bucket rig.	Nonfailing.
33	....	.....do......	95	33.7	30.7	3.0	.....do..........	Do.
38	Harriet B. Coley	Plain........	130	21.5	20.1	1.4	.....do..........	Nonfailing. For assay see p. 108.
39	....	.....do......	125	20.3	19.6	.7	Windlass rig....	Nonfailing.

WESTPORT.

AREA, POPULATION, AND INDUSTRIES.

Westport is one of the shore towns of Connecticut, and is near the middle of the Long Island Sound boundary of Fairfield County, just east of Norwalk and midway between Bridgeport and Stamford. The area of the town is about 20 square miles. Most of Westport is cleared, but there are patches of woodland here and there which aggregate 4 square miles or a fifth of the total area of the town. The territory was taken from Fairfield, Norwalk, and Weston and incorporated as a separate town in 1835. In 1910 the population was 4,259, an increase of 242 over the population of 1900. There are about 217 inhabitants to the square mile. The following table shows the population at each census since the town was founded and also the percentage of change during the preceding decade:

Population of Westport, 1840–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1840..............................	1,803	....	1880..............................	3,477	+3
1850..............................	2,651	+47	1890..............................	3,715	+7
1860..............................	3,293	+24	1900..............................	4,017	+8
1870..............................	3,361	+ 2	1910..............................	4,259	+6

[a] Connecticut Register and Manual, 1919, p. 641.

For the first 35 years there was a rapid growth, which was due in part to the opening of the New York & New Haven Railroad in 1849, and in part to the establishment of manufactures of cotton and leather. Since then there has been a steady though moderate growth. Westport is now primarily a district of country residences belonging to New York people. It is probable that because of the nearness of New York City and the excellent transportation facilities the population of Westport will continue to grow.

Westport is the principal settlement and is at the head of the estuary of Saugatuck River. Nearer the mouth is the village of Saugatuck. A third settlement, Greens Farms, is on the Sound near the southeast corner of the town. There are about 70 miles of highways in the town. About 5 miles of the Boston Post Road, one of the State trunk-line highways, lies within the area. There are also 3 or 4 miles of roads built with State aid. The grades are in general moderate, and the road surfaces are well kept. There is trolley connection from Westport village along the Boston Post Road to Bridgeport and Stamford, and along the west shore of Saugatuck River to Saugatuck, and thence eastward to Compo Beach. The main line of the New York, New Haven & Hartford Railroad runs east and west across the town half a mile to a mile from the Sound shore. It has a station at Saugatuck known as "Westport and Saugatuck" and also a station at Greens Farms. There are post offices at Westport, Saugatuck, and Greens Farms, and rural delivery from Westport to the outlying districts.

The principal industries of Westport are agriculture and the manufacture of cotton twine, buttons, embalming fluid, undertaker's supplies, mattresses and cushions, hatter's leather, and starch.

SURFACE FEATURES.

The features characteristic of the western highlands of Connecticut are found in Westport in a form modified by nearness to the sea. The hills and ridges show a distinct north-south alinement. The hills a mile or so back from the shore are 100 to 180 feet high. The hills farther inland are higher, and the greatest elevation in the town is on a ridge in the northeast corner, which has its crest 240 feet above sea level. The valleys in general trend southward. The valley of Saugatuck River is at least 200 feet deep at Westport village. The rock walls rise 120 feet above the water level, and soundings for abutments for a new bridge showed that in places the rock floor is at least 80 feet below sea level. These facts show that the coast formerly stood higher than it does now and that it has been depressed. In this way the valley of the Saugatuck has been drowned and made an estuary. Mud Brook valley, though smaller, has had a similar history, and Sherwood Pond is its estuary.

Most of Westport is drained by Saugatuck River, which enters the town near the northwest corner. Half a mile south of the Weston town line it is joined by Aspetuck River, which flows parallel to the north boundary. Several other tributaries, including its West Branch, Stony Brook, and Deadman Brook, enter Saugatuck River. Sasco Brook, Mud Brook, and two other unnamed short brooks drain the southeastern part of the town and discharge directly into Long Island Sound.

WATER-BEARING FORMATIONS.

Gneiss.—The following bedrock formations have been recognized in Westport:[1] The Thomaston granite gneiss, the Danbury granodiorite gneiss, and the Waterbury gneiss.

All of the area west of Saugatuck River and a strip east of the river 2 miles wide along the shore and 1 mile wide at the north boundary, an area a quarter to half a mile wide extending along Sasco Brook for 2 miles above its mouth, and a little area in the northeast corner of the town are underlain by the Thomaston granite gneiss. These areas aggregate over 13 square miles. The Thomaston is a typical granite gneiss composed of medium coarse grains of feldspar quartz, flakes of black mica, and minor accessory minerals. The mica is more or less perfectly segregated in narrow bands. The mica flakes are roughly parallel to one another and give the rock its cleavable character. This rock is in general light gray in color, but some phases of it are pink.

The Danbury granodiorite gneiss is similar to the Thomaston granite gneiss except that the black mineral is in large part hornblende instead of mica. This formation underlies about 3½ square miles in a strip a mile and a quarter wide and including Prospect Hill. From Prospect Hill the band runs west and north-northwest to the Wilton town line.

The bedrock of the remainder of the town (3 square miles) is the Waterbury gneiss. One patch, half a mile wide at its north end and a mile and a half wide along the Sound, extends northward 2 miles from Greens Farms. A second small patch lies near the north part of the east boundary. Originally this rock was a series of sandstones and shales but was converted by metamorphism to a schist. Contemporaneously with or subsequently to the metamorphism there was injected into it a great deal of igneous material. Most of these intrusions are thin granitic sheets that follow the schistose layers or cross them here and there like dikes. About three-quarters of a mile west of Sasco Brook on the Boston post road there is a trap dike about 60 feet wide, which outcrops on both sides of the highway and may be traced a little way beyond.

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

All the bedrock formations of Westport carry water in the same way and in equal abundance. There are no porous zones of consequence, and there is no interstitial water. Water may be recovered in moderate amounts by means of drilled wells, a good many of which have been made in Westport. The water is carried in part in joints formed by the original cooling and shrinkage of the rock, and in part in fissures formed by the compressive stresses to which the rock has been subjected. The ground water of the overlying soil mantle is derived from rain water by absorption and is in part discharged into the maze of intercommunicating joints and fissures in the bedrock. The probability is that a drill hole sunk at any point will cut one or more of these water-bearing fissures within a rather short distance and obtain a satisfactory supply of water. Statistics of a number of such wells in Westport are given in the table on page 117.

Till.—The mantle rock of the higher portions of Westport, comprising three-fifths of the total area, is till—a dense deposit composed of rock flour, clay, silt, and sand, which form a matrix in which are embedded pebbles and boulders. The distribution of the larger fragments is entirely fortuitous. The till was made by the abrading action of the glacier, which moved over the region in a southerly direction. The mantle of residual soil or decayed rock formed in preglacial time and some of the fresh, unweathered rock below were scraped away and carried along by the ice. The load of débris was in part carried to the southern edge of the ice sheet, but most of it was plastered like a blanket over the glaciated rock surface. The weight of the ice sheet tended to pack the till, so that the grains interlock and make a dense, tough material. There are many minute interstices that are capable of absorbing part of the rain that falls. The water first soaks downward through the till until it is deflected horizontally, and then it moves along until it is naturally discharged again at the surface in springs or swamps. The water may also be artificially recovered by digging wells in the till. Late in October and early in November, 1916, 49 such wells were visited in Westport. Of these wells 25 are said by the owners to be nonfailing and 13 are said to fail. The reliability of the other 11 wells could not be ascertained. The data collected concerning these wells are tabulated in detail on pages 115–116 and are summarized in the following table:

Summary of wells dug in till in Westport.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	31.9	24.8	11.4
Minimum	10.0	6.9	.6
Average	18.1	14.7	3.4

Stratified drift.—The low-lying portions of Westport, aggregating two-fifths of the total area, are covered with stratified drift, which includes all materials that have been sorted and deposited in beds and lenses, in each of which the sand or gravel is of essentially uniform size.

The stratified drift of the broad valley east of Saugatuck River in the northwestern part of the town and that west of Sasco Brook seem probably to be of glaciofluviatile origin. When the glacier receded from this region many streams of melt water flowed from it and carried heavy loads of débris, which were deposited in front of the glacier. These deposits may, however, be later deposits analogous to the alluvium of the flood plains of the present streams. The principal reason for supposing them to be glacial outwash is that they extend 40 or 50 feet above the present stream level. In a zone a mile or so wide along the shore of Long Island Sound are deposits of stratified drift which may be of marine origin and analogous to the present sands and gravels of the beaches.

In the present discussion the origin of these deposits is of less importance than their character and distribution. The map (Pl. III) shows the areas of stratified drift. The stratified drift is formed in large part by the reworking of the till. The porosity in terms of the percentage of the whole volume not occupied by sand or other grains is greater than in till, and the individual pores are larger, so that the circulation of ground water is greatly stimulated. Wells dug in stratified drift are likely to yield more abundant supplies than wells dug in till. Fourteen such wells were visited in Westport and of these eight were said to be nonfailing. The data collected are given in detail in the table on pages 116–117 and are summarized in the following table:

Summary of wells in stratified drift in Westport.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	27.8	26.4	3.9
Minimum	8.5	6.4	1.0
Average	17.1	15.0	2.1

QUALITY OF GROUND WATER.

The accompanying table gives the results of two analyses and four assays of samples of ground water collected in the town of Westport. Nos. 24, 52, and 56 are very soft and low in mineral content: the rest are soft and only moderately mineralized. In so far as chemical analysis may be used as a criterion the waters are acceptable for domestic use. No. 24, however, is so high in nitrate

that a sanitary inspection would be warranted. Nos. 49 and 55 are a little high in scale-forming ingredients and are therefore rated as fair for use in boilers, but the rest are probably good for boiler use.

Nos. 24, 39, and 56 are sodium-carbonate waters, Nos. 49 and 52 are calcium-carbonate in type, and No. 55 is a calcium-chloride water.

Sample 39 was collected from a well dug into sandy soil a few hundred feet from the shore at Compo Beach. It is probable that the relatively high chloride content, 30 parts per million, is due to the proximity to salt water and frequent blowing over of salt spray, and not to pollution by either salt water or sewage. The low value of the nitrates and the cleanly surroundings of the well indicate that the water is not polluted by sewage. Sea water contains about 3.3 per cent of dissolved matter, of which about 55 per cent is chloride. This is equivalent to 1.815 per cent, or 18,150 parts per million. A mixture of one part of sea water with about 600 parts of pure water would contain about 36 parts per million of chloride. Therefore it seems more reasonable to ascribe the high chloride in this well to salt spray blown onto the surrounding soil and leached out than to infiltration of sea water.

Chemical composition and classification of ground waters in Westport.[a]

[Parts per million: collected Dec. 8, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. II.]

	Analyses.[b]		Assays.[c]			
	24	[d] 39	49	52	55	56
Silica (SiO_2)	19	11	....	....	....	....
Iron (Fe)	.12	.32	0.35	0.46	0.33	Trace.
Calcium (Ca)	8.9	22	....	....	....	....
Magnesium (Mg)	2.1	6.0	....	....	....	....
Sodium (Na)	[e] 17	32	[e] 23	[e] 11	[e] 17	[e] 14
Potassium (K)		4.7				
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	34	90	100	38	27	45
Sulphate radicle (SO_4)	18	49	17	10	27	12
Chloride radicle (Cl)	7.0	30	10	8.4	49	7.4
Nitrate radicle (NO_3)	14	4.4	....	....	....	....
Total dissolved solids at 180° C	104	218	[e] 150	[e] 86	[e] 170	[e] 93
Total hardness as $CaCO_3$	[e] 31	[e] 80	68	32	85	32
Scale-forming constituents [e]	49	86	95	55	110	55
Foaming constituents [e]	46	100	60	30	50	40
Chemical character	Na-CO_3	Na-CO_3	Ca-CO_3	Ca-CO_3	Ca-Cl	Na-CO_3
Probability of corrosion [f]	(?)	(?)	N	(?)	(?)	N
Quality for boiler use	Good.	Good.	Fair.	Good.	Fair.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 115-117.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Collected Dec. 9, 1916.
[e] Computed.
[f] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

PUBLIC WATER SUPPLIES.

The Westport Water Co. has been supplying water since 1892. The source of supply at present consists of two wells (Nos. 66 and 67,

Pl. II) dug in the stratified drift of the flood plain of Saugatuck River a little north of the village. Water is pumped from these wells by two Gould triplex, single-acting pumps with 8 by 10 inch cylinders, driven at 40 revolutions a minute by electric motors. There is also an auxiliary direct-acting Blake steam pump. The water is delivered to a 240,000-gallon steel standpipe on a hill half a mile north of the village. From the standpipe the water runs by gravity through 20.2 miles of main to 81 hydrants and 544 service taps, of which 370 are metered. The normal pressure is 60 to 65 pounds to the square inch, but by pumping direct into the mains it may be increased to 90 pounds for fire service. Of the 3,400 people in the area served, about 3,200 are supplied and consume about 240,000 gallons a day. According to Mr. F. B. Hubbell, the superintendent of the company, the wells are dug in moderately coarse gravel. The "old" well (No. 66) on the east side of the Saugatuck is rectangular, 20 feet wide and 40 feet long, and 10 or 11 feet deep. It usually contains 6 or 7 feet of water. The "new" well (No. 67) is on the west side of the Saugatuck and is connected with the pumping plant by a suction main a quarter of a mile long. This well is circular, 30 feet in diameter, and about the same depth as the older well. The wells will yield together about 50,000 gallons an hour.[1] Both wells are roofed to keep out wind-blown foreign matter and the water is effectually filtered in percolating through the sand and gravel of the flood plain. The water is of good quality and is of sufficient abundance to care for a slowly growing population. At all events the flood plain of Saugatuck River can be made to yield much more water by the construction of additional wells.

RECORDS OF WELLS.

Wells dug in till in Westport.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Slope.......	160	23.9	12.5	11.4	Two-bucket rig....	
7	....	...do.......	100	18.6	16.0	2.6	Two-bucket rig and house pump.	
8	....	...do........	80	16.0	14.6	1.4	Two-bucket rig....	Nonfailing.
9	....	...do........	115	10.8	8.3	2.5	.....do............	
10	....	...do........	230	23.0	21.4	1.6	Windlass rig......	Fails.
11	....	...do........	230	20.5	19.2	1.3	.....do............	Do.
12	....	Swale......	190	15.9	9.7	6.2	One-bucket rig....	
14	F. L. Church....	Plateau....	205	20.4	16.6	3.8	....	Fails; abandoned.
15	....	Knoll......	125	19.7	16.8	2.9	Windlass rig.......	Nonfailing.
16	....	Plateau....	150	25.5	18.4	7.1	Two-bucket rig....	Nonfailing. Rock bottom.
17	....	Slope.......	125	15.2	13.2	2.0	.....do............	Fails.
18	....	.....do......	135	23.0	21.2	1.8	.....do............	
19	....	Plateau....	120	29.5	24.1	5.4	.....do............	Nonfailing.
20	....	...do.......	130	17.5	14.6	2.9	.....do............	Abandoned.

[1] Connecticut Public Utilities Commission Rept., 1917.

Wells dug in till in Westport—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
23		Slope	90	24.0	19.8	4.2	Windlass rig	Nonfailing.
25		do	175	16.4	14.9	1.5	Two-bucket rig and house pump.	Nonfailing. Rock bottom.
26		do	95	11.3	9.0	2.3	Two-bucket rig	Do.
27		do	115	18.4	16.9	1.5	Two-bucket rig and air-pressure system.	Do.
28		do	120	17.5	13.5	4.0	Two-bucket rig and house pump.	Do.
29		do	190	18.9	17.3	1.6	Two-bucket rig	
30		do	120	13.6	6.9	6.7	do	Do.
31		do	100	24.5	23.2	1.3	House pump	Fails.
32		Hill	105	17.9	17.0	0.9	Chain pump	Do.
33		Slope	95	14.1	12.0	2.1	Two-bucket rig	
35		do	60	14.8	12.5	2.3	do	Nonfailing.
36		do	45	18.3	10.3	8.0	do	Do.
40		do	80	18.4	16.0	2.4	Chain pump and house pump.	Fails.
41		do	55	26.0	20.8	6.8	Chain pump	
42		do	20	12.6	11.9	0.7	Two-bucket rig	Do.
45		Hill top	30	31.9	21.2	10.7	Chain pump	Nonfailing. Rock 10 feet.
46		Plateau	140	19.0	15.2	3.8	Two-bucket rig	Nonfailing.
47		Slope	130	27.6	24.8	2.8	Windlass rig and house pump.	Do.
48		do	165	12.1	10.4	1.7	Chain pump and house pump.	Do.
50		do	75	14.1	10.6	3.5	Sweep rig	Fails.
51		Plain	65	12.9	9.6	3.3	Two-bucket rig	Nonfailing
53		Slope	35	11.0	10.1	0.9	do	Fails.
54		Plain	45	16.1	13.8	2.3	Chain pump	Do.
56	G. P. Jennings	Slope	35	10.0	8.0	2.0	do	Nonfailing. For assay see p. 114.
57		do	30	10.5	9.9	0.6	Two-bucket rig	Fails. Rock bottom.
58		do	45	11.0	9.7	1.3	Chain pump	Fails.
59		do	30	19.8	17.6	2.2	Windlass rig	Nonfailing.
60		do	35	14.8	12.5	2.3	Two-bucket rig	Do.
62		do	35	20.0	14.8	5.2	Two-bucket rig and house pump.	
63		do	10	11.1	9.2	1.9	Chain pump	Do.
64		do	130	15.4	14.4	1.0	Two-bucket rig and house pump.	Do.
65		Plain	125	16.4	14.6	11.4	Windlass rig	Do.

Wells dug in stratified drift in Westport.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
2		Plain	135	18.5	16.9	1.6	Two-bucket rig	
3		do	130	27.8	26.4	1.4	do	
4		do	160	22.5	20.7	1.8	do	
5		do	55	18.9	16.2	2.7	do	
6		do	75	18.6	12.0	1.6	Windlass rig and house pump.	Nonfailing.
21		Slope	15	10.1	6.4	3.7		Do.
22		Ridge	20		12.0			(a)
24	G. W. Harris	Plain	55	11.6	10.6	1.0	Two-bucket rig	Nonfailing. For analysis see p. 114.
34		Slope	25	11.6	7.7	3.9	do	Nonfailing.
37		Plain	25	23.3	22.1	1.2	Windlass rig	Do.

a Three attempts to make driven wells have been made on this bar. A little fresh water was obtained in each at 12 to 14 feet, but below this only salt water was found.

Wells dug in stratified drift in Westport—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
38	....	Slope	25	21.9	20.0	1.9	Two-bucket rig.	Nonfailing.
39	Merritt Gault..	Plain	10	8.5	6.5	2.0	.....do..........	Nonfailing. For analysis see p. 114.[a]
49	John Barlow...	Slope	55	11.7	8.7	3.0	Two-bucket rig.	Nonfailing. For assay see p. 114.
52	B.F. Bulkley, jr	Terrace	25	25.6	21.3	4.3	Windlass and counterbalance rig.	Nonfailing. Never less than 14 inches of water. Rock bottom. For assay see p. 114.
55	....	Slope	45	13.1	10.9	2.2	Chain pump....	Nonfailing. For assay see p. 114.
66	Westport Water Co.	Plain	....	11.0	4.0	7.0	([b])	Nonfailing.
67	.....do........	.....do.....	....	11.0	....	....	([b])	

[a] The water from this well is quite potable, though slightly salty. Satisfactory supplies are obtained by wells 8 feet deep on the plain around this well. Deeper wells yield salty water.
[b] Further information on these wells is given in the discussion of public water supplies on p. 114–115.

Drilled wells in Westport.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth of water in well.	Diameter.	Yield per minute.	Kind of rock.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Gallons.*	
13	F. L. Church...........	Plateau.....	100	195±	9	....	....	....	
43	Lawrence Donahue.....	Slope......	40	....	....	....	....	....	
44	George Gair............	....	25	....	....	....	....	....	
61	Childe Child or E. T. Bedford.	Slope......	35	....	....	....	....	....	
([a])	Atlantic Starch Works..	Valley.....	....	215	34	15	8 and 6	60	Gneiss
([a])	Dr. Graham Hammond.	....	....	148	30	....	....	5	Schist.
([a])	A. W. Smith...........	Hilltop.....	....	94	15	30	6	15	Do.

[a] Data from Gregory, H. E., and Ellis, E. E., Underground water resources of Connecticut: U. S. Geol. Survey Water-Supply Paper 232, 1909.

WILTON.

AREA, POPULATION, AND INDUSTRIES.

Wilton lies a little southwest of the center of Fairfield County, and on the west touches New York State. Norwalk and Ridgefield lie respectively to the south and north. The area of the town is 28 square miles. There are woods scattered over the town, but especially along the west and north margins. They have an aggregate area of a little over 12 square miles or 45 per cent of the whole area of the town.

The first settlement in Wilton was made from Norwalk about 1701, and in 1726 it had become large enough to be organized as Wilton Parish. In 1802 the territory was incorporated as a separate town. The population in 1910 was 1,706, an increase of 108 over the previous census return. There are about 60 inhabitants to the square

mile. The following table shows the changes in population since 1810:

Population of Wilton, 1810 to 1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1810	1,728		1870	1,994	−10
1820	1,818	+5	1880	1,864	−7
1830	2,097	+15	1890	1,722	−8
1840	2,053	−2	1900	1,598	−7
1850	2,066	+1	1910	1,706	+7
1860	2,208	+7			

[a] Connecticut Register and Manual, 1915, p. 656.

There was in general a fair growth until 1860, followed by a considerable diminution until 1900. The last decade has shown a slight increase. Since 1890 there have been fewer people in Wilton than there were in 1810. As in many other portions of New England, the loss of population in the middle and later parts of the nineteenth century is to be ascribed to the greater attractions of other regions. Some of the emigrants went to the manufacturing towns near by, and others went to the richer and more easily tilled farming regions in the West. During the last decade a number of country residences have been built in Wilton. With the development of good roads and of the automobile Wilton has become quite accessible, and its scenic value is being realized and developed. It is probable that this growth will continue for some time, but it seems improbable that there will be any large settlements in the near future.

The principal settlements are Wilton and Cannondale on Norwalk River. Parts of Georgetown and Branchville spread over into Wilton. North Wilton and Bald Hill Street northwest of Wilton, and Hurlbutt Street to the east are small villages. The Norwalk and Danbury turnpike follows the valley of Norwalk River through Wilton. This 8-mile piece of road and a piece 5 miles long from Wilton through North Wilton and Bald Hill Street to the Ridgefield town line are State trunk-line roads. The town keeps in repair about 60 miles of dirt road. The Danbury branch of the New York, New Haven & Hartford Railroad, which joins the main line at South Norwalk, also follows Norwalk River through the town. It has stations at South Wilton, Wilton, Cannondale, Georgetown, and Branchville. There are post offices at Wilton, Cannondale, and Georgetown, and rural-delivery routes have been established over all the town. Agriculture is the principal industry.

SURFACE FEATURES.

The topography of Wilton is rugged and diversified. Between the valleys are ridges and elongated hills which trend north and south. In the northern part of the town the crests have elevations of 620

to 660 feet above sea level. Separated from this highland by a zone about 2 miles wide for which no general statement of elevation can be made is the southern part of the town, in which the hilltops range from 360 to 400 feet above sea level. The set of projected hill profiles in figure 16 shows how these two groups of hills have a steplike relation to each other. The sections bear about north-northwest. These hilltops are believed to be fragments of an old plain or stepped

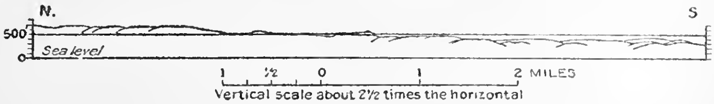


FIGURE 16.—Projected north-south profile across Wilton showing terraced character of the plateau.

plain which has been uplifted and had valleys cut in it. Norwalk River is the master stream and has the deepest valley. A comparison of figure 17, which is an east-west profile across Wilton on the line *B–B′*, on the maps (Pls. II and III), with the composite north-south profile of figure 16 will bring out these points. The lowest point in Wilton is where Norwalk River crosses the south boundary at an elevation of 110 feet above sea level, and the greatest elevation, 700 feet, is near the west end of the north boundary.

A strip of country 2 to 4 miles wide through the middle of the town is drained by Norwalk River and its tributaries. On one tributary, between Wilton and North Wilton, is the North Wilton reservoir of the South Norwalk waterworks. The west margin of Wilton is in the drainage basin of Silvermine River, and includes three of the reservoirs of the South Norwalk supply. The south part of the east border is drained by the West Branch of Saugatuck River.

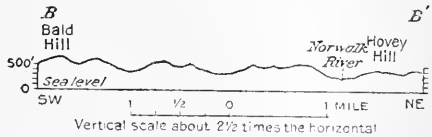


FIGURE 17.—Profile across Wilton (section *B–B′* on Pls. II and III) showing dissection of the terraced plateau.

WATER-BEARING FORMATIONS.

Gneiss and schist.—Four varieties of bedrock have been recognized in Wilton.[1] The Becket granite gneiss, which underlies a strip half a mile wide along the south boundary, is a schist into which have been injected many thin dikes and sheets of igneous rock, chiefly granitic. The injected material is so abundant that it gives the rock its dominant character.

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

The Berkshire schist, which underlies the valley of Norwalk River north of Hovey Hill, is a gray mica schist, composed essentially of quartz and mica. It has been extensively injected by granite intrusions but not to the same degree as the Becket granite gneiss, which in places it closely resembles. The injected material has feldspar in addition to quartz and mica so that it is more massive than the laminated schists. There has been some development of red garnet and of staurolite in the limy parts of the schist.

The bedrock of Hovey Hill and Sturgis Ridge is the Thomaston granite gneiss, as is also that of a strip a mile wide extending west from Chestnut Hill across Belden Hill to the west boundary and thence north to Ridgefield. This granite gneiss is a light-gray or pinkish-gray medium coarse grained rock, composed essentially of feldspar, quartz, and black mica—the minerals that characterize a granite. There are also small amounts of accessory minerals. Metamorphism has produced gneissoid structure in the rock. Foliation planes, marked by concentration and parallel orientation of mica flakes, have been made. These foliation planes give the rock its banded appearance and its tendency to cleave along certain planes. Locally this rock is so strongly metamorphosed as to resemble the Becket gneiss.

The middle part of the town, including Wilton, Comstock Knoll, Turner Ridge, North Wilton, and a strip northwest into Ridgefield is underlain by Danbury granodiorite. This rock is similar to the Thomaston granite gneiss except that the mica is in large part replaced by hornblende.

The water-bearing properties of these four types of bedrock are alike and may be discussed together. These rocks have very little porosity, and no interstitial water is to be expected. The spaces between the grains are so minute that they can contain but little water, and their narrowness tends to increase friction and so retard circulation. The mechanical stresses to which the rocks have been subjected have made many openings in them. These openings may be recognized as intersecting systems of joints and fissures. In general one set is horizontal or slightly inclined and is cut by one, two, or more vertical or steeply inclined sets of crevices. Their mutual intersection forms a ramifying and interconnecting network of channels through which water may circulate. Water from the saturated base of the overlying soil finds its way and circulates through the network of fissures and may be recovered by means of drilled wells. The data available concerning such wells in Wilton are given in the table on page 124.

Till.—Till forms the mantle rock of most of Wilton. It is the product of direct glacial action and consists of the débris plucked and scraped up by the ice. The fragments have been carried along in the

ice, rubbed against one another and against the rock bed on which the ice moved, and thus worn and polished and eventually deposited in a heterogeneous mass. Pebbles, cobbles, and boulders are embedded in a dense matrix of the finely ground rock. The whole mass is a very tough material, in part because of the compacting and pressing by the weight of the overlying ice and in part because the angular grains interlock. This interlocking also tends to reduce the porosity of the till, for the smaller particles are fitted into the interstices of the larger ones. There is, however, much pore space, for the till absorbs, stores, and transmits large amounts of water. Wells dugs into till will in general procure supplies of water sufficient for domestic and farm needs. During late October and early November, 1916, 46 such wells were visited in Wilton. Two were dry at the time, 10 more were said to fail, and 25 to be nonfailing. The reliability of the remaining 9 could not be ascertained. The data obtained are tabulated in detail on pages 122–123 and are summarize in the following table:

Summary of wells dug in till in Wilton.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	34.1	30.9	8.7
Minimum	7.0	4.2	.4
Average	17.0	13.6	3.1

Stratified drift.—There are narrow areas of stratified drift along parts of the valley of Norwalk River, and also in two broader valleys, one near Bald Hill Street and one near Chestnut Hill. The distribution of these areas is shown on the map (Pl. III). Streams which have eroded the till have sorted and washed the constituents and redeposited them in the lowlands. The principal difference between the two deposits is that the individual beds of the stratified drift contain only grains that have a narrow range of variation of size. The smaller grains have been removed, so that the interstices of the larger ones are open, and therefore the stratified drift is far more porous and a better water bearer than the till. Wells in the stratified drift are apt to give more abundant supplies than wells in till. Data were obtained concerning two driven and eight dug wells in stratified drift in Wilton. All are said to be nonfailing. The data collected are tabulated in detail on page 123 and are summarized in the following table:

Summary of wells in stratified drift in Wilton.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	21.3	19.8	5.0
Minimum	9.7	8.0	1.5
Average	15.4	13.3	2.5

QUALITY OF GROUND WATER.

The following table gives the results of two analyses and three assays of samples of ground water collected in the town of Wilton. The waters are all low in mineral content and are soft except Nos. 56 and 46A, which are very soft. All are suitable for use in boilers and so far as may be judged from their chemical composition are acceptable for domestic use. Nos. 29 and 43 are calcium-carbonate in type, and the rest sodium-carbonate.

Chemical composition and classification of ground waters in Wilton.[a]

[Parts per million; collected Dec. 8, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. II.]

	Analyses.[b]		Assays.[c]		
	42	56	29	43	46A
Silica (SiO_2)	27	10			
Iron (Fe)	.38	.04	0.61	0.58	0.80
Calcium (Ca)	13	8.0			
Magnesium (Mg)	4.9	3.6			
Sodium and potassium (Na+K)[d]	16	12	11	8	11
Carbonate radicle (CO_3)	.0	.0	2.4	.0	.0
Bicarbonate radicle (HCO_3)	58	37	70	62	36
Sulphate radicle (SO_4)	16	20	11	12	5.0
Chloride radicle (Cl)	16	6.2	4.6	5.2	4.0
Nitrate radicle (NO_3)	1.2	.44			
Total dissolved solids at 180° C	124	82	[d]110	[d]100	[d]70
Total hardness as $CaCO_3$	[d]53	[d]35	57	54	18
Scale-forming constituents[d]	74	40	80	80	45
Foaming constituents[d]	43	32	30	20	30
Chemical character	Na-CO_3	Na-CO_3	Ca-CO_3	Ca-CO_3	Na-CO_3
Probability of corrosion[e]	(?)	(?)	N	(?)	N
Quality for boiler use	Good.	Good.	Good.	Good.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 122-124.
[b] For methods used in analysis and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Computed.
[e] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

RECORDS OF WELLS.

Wells dug in till in Wilton.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	Geo. W. Godfrey.	Plain	325	10.2	8.1	2.1	Sweep rig	Nonfailing.
4		Slope	400	15.1	14.0	1.1	Chain pump	Fails.
5		do	590	9.9	9.0	.9	Sweep rig	Do.
6		do	595	11.7	8.4	3.3	Two-bucket rig	
7		do	600	12.6	9.0	3.6	Sweep rig	Nonfailing. Tiled.
8		do	550	25.5	20.2	5.3	Windlass rig	Nonfailing.
9		Ridge	575	28.1	21.6	6.5	Two bucket rig	Do.
10		Plateau	530	13.7	11.0	2.7	do	Do.
11		Slope	530	23.8	15.1	8.7	Chain pump	
12		do	465	10.9	7.6	3.3	Sweep rig	
13		do	480	34.1	30.9	3.2	Two-bucket rig	Do.
15		do	610	17.1	16.5	.6	Sweep rig	Fails.
16		Ridge	605	17.0	14.5	2.5	Two-bucket rig	Fails. Rock, 8 feet.
17		Slope	520	12.4	10.4	2.0	do	Nonfailing.
18		Ridge	610	21.0	16.2	4.8	do	Fails.
19		Hilltop	560	15.8	14.0	1.8	do	Nonfailing.

Wells dug in till in Wilton—Continued.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
20	....	Slope......	390	8.5	5.6	2.9	Sweep rig.........	
21	....	.....do.....	510	15.5	11.9	3.6	Chain pump......	Nonfailing.[a]
22	....	.....do.....	470	20.0	19.6	.4	Two-bucket rig...	Fails.
23	Edw. W. Olmstead.	.....do.....	420	19.1	18.4	.7	No rig............	Fails. Rock, 6 feet.
24	.....do.......	Hilltop....	460	12.3	10.0	2.3	Windlass rig and gravity system.	Nonfailing.
25	....	.....do.....	440	21.0	17.0	4.0	Two-bucket rig and house pump.	Do.
27	....	Slope......	330	7.0	4.2	2.8	House pump......	Do.
27A	....	.....do.....	340	18.5	17.5	1.0	No rig............	Fails.[b]
29	....	.....do.....	245	16.5	13.2	3.3	Two-bucket rig...	Nonfailing. For assay see p. 122.
30	....	.....do.....	280	11.4	9.9	1.5	Chain pump......	Nonfailing.[c]
30A	....	.....do.....	275	13.2	6.2	7.0	.....do............	Do.[c]
31	....	.....do.....	375	18.9	14.7	4.2	Two-bucket rig....	Do.
32	....	.....do.....	370	18.2	14.0	4.2	Sweep rig and house pump.	Do.
33	....	Plateau....	360	21.6	18.2	3.4	Two-bucket rig...	
34	....	Slope......	365	12.3	8.3	4.0	.....do............	Nonfailing.
35	....	.....do.....	290	13.6	8.1	5.5	Windlass and pulley rig.	
36	....	.....do.....	210	15.1	13.5	1.6	Two-bucket rig...	Do.
39	....	.....do.....	280	19.1	18.5	.6	.....do............	Fails.
40	....	Plain......	260	22.7	21.0	1.7	.....do............	Nonfailing.
41	....	Slope......	280	12.2	9.8	2.4	Windlass rig......	Fails. Rock bottom.
47	....	.....do.....	445	29.2	23.6	5.6	....	Nonfailing. Rock, 4 feet.
48	....	.....do.....	315	22.3	16.8	5.5	Two-bucket rig...	
49	....	.....do.....	360	31.6	......	Dry.	Windlass rig......	Fails. Rock, 22 feet.
50	....	.....do.....	275	18.0	13.4	4.6	One-bucket rig....	
51	....	.....do.....	265	15.4	11.8	3.6	.....do............	Nonfailing.
52	....	.....do.....	290	14.6	10.9	3.7	Two-bucket rig...	Do.
55	....	.....do.....	225	14.0	9.3	4.7	.....do............	Do.
57	....	.....do.....	260	15.5	12.7	2.8	.....do............	Do.
58	....	.....do.....	235	21.1	18.1	3.0	No rig............	
59	....	Swale......	285	8.9	6.1	2.8	Windlass rig......	Do.
60	....	Slope......	355	25.5	......	Dry.	Chain pump......	Fails.

[a] In a depression filled with till between two rock ledges.
[b] Rock bottom well, on slope above well No. 27, and 150 feet distant.
[c] Well No. 30 southwest of house; No. 30A, northeast.

Wells dug in stratified drift in Wilton.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
37	....	Slope....	180	21.3	19.8	1.5	Windlass rig and house pump.	Nonfailing.
42	Martin Harbs.....	Plain....	205	9.7	8.0	1.7	Deep-well pump.	Nonfailing. For analysis see p. 122.
43	New York, New Haven & Hartford R. R.......	.....do....	180	12	......	......	Pitcher pump...	Nonfailing. Driven well. For assay see p. 122.
44	....	.....do....	195	18.0	16.5	1.5	Chain pump.....	Nonfailing.
45	....	.....do....	180	15.9	14.0	1.9	Two-bucket rig.	Do.
46	Irving Pleasant..	Slope.....	175	18.5	17.0	1.5	.....do..........	Do.
46A	.....do..........	....	175	18	13	5	Pitcher pump..	Nonfailing. Driven well. For assay see p. 122.
53	....	Plain.....	180	11.5	9.0	2.5	Two-bucket rig.	Nonfailing.
54	....	.....do....	165	11.2	9.5	1.7	.....do..........	Do.
56	Miss H. S. Willing.	.....do....	135	17.8	13.0	4.8	.....do..........	Nonfailing. For analysis see p. 122.

Drilled wells in Wilton.

No. on Pl. II.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water in well.	Diameter.	Yield per minute.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Gallons.*
2	John Hollowell	Slope	320	72	14			
3	School	do	350	200				
14	Odenwald	do	465	75				
25	Street	do	440					
28	Middlebrook	do	370					
38	Freeman	do	315					
61	Egbert Lilly	do	360					
62	Henry Finch	do	350					
63	P. M. Comstock	do	375					
63A	do	do	365					
64	J. E. Kayser	do	550	51	15	20	6	5

EAST GRANBY.

AREA, POPULATION, AND INDUSTRIES.

East Granby is a farming town in the north-central part of Hartford County and lies about 15 miles north of the city of Hartford. The town has an area of about 18 square miles, of which nearly 8 square miles, or 43 per cent, is woodland. The woods are well distributed but are for the most part restricted to the hills.

The territory of East Granby was taken from Granby and Windsor Locks in 1858 and incorporated as a separate town. The population in 1910 was 797, an increase of 113, or 17 per cent, over the population in 1900. The following table shows the population at each census from 1860 to 1910, together with the per cent of change in the decade:

Population of East Granby, 1860–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1860	833		1890	661	−12
1870	853	+2	1900	684	+ 3
1880	754	−12	1910	797	+17

[a] Connecticut Register and Manual, 1919, p. 638.

There has been no uniform trend of change of population, but it has fluctuated in both directions. During the last decade there has been a considerable development of the culture of leaf tobacco for cigar wrappers and binders, and this probably accounts for the notable increase in population. Because of its inferior transportation facilities the town will probably remain a farming district, and will grow only moderately in the future. The present density of population is 45 inhabitants to the square mile.

The principal settlement is East Granby, in the eastern part of the town, where there are stores and a post office. There is a smaller

village at Granby Station and part of Tariffville extends into East Granby. Spoonville is a small settlement on Farmington River in the southeast corner of the town. There are about 32 miles of roads in the town, which are for the most part excellent, though the roads in the easternmost part are very sandy. The road from Tariffville to Granby Station and the road from Tariffville through East Granby to West Suffield are of excellent macadam. The Central New England Railway runs past the south boundary of East Granby and has a station at Tariffville. A branch runs north from Tariffville to Springfield and has a station at East Granby. The Northampton division (Canal Road) of the New York, New Haven & Hartford Railroad follows the west boundary and has a station at Granby Station and a flag station at Floydville, a mile south.

SURFACE FEATURES AND GEOLOGIC STRUCTURE.

East Granby comprises a nearly level sand plain, 160 to 200 feet above sea level, above which rise a large till-covered hill and several smaller ones. The stream valleys are cut into this plain. The lowest point in the town is where Farmington River passes the southeast corner, about 100 feet above sea level, and the highest point is the crest of Peak Mountain, 665 feet above sea level. The total relief is thus about 565 feet.

The sand plain is separated into two parts by the large till-covered trap ridge. It was formed by the deposition of vast amounts of débris washed out from the glacier as it receded from this region and so constitutes an outwash plain. The boundary of the stratified drift lies in general 200 to 240 feet above sea level. Above this height the mantle rock is till, the direct product of glaciation.

The stratified drift forms a very loose, sandy soil, and its upper portion becomes very dry in times of drought, although there may be an abundance of water at some depth. The ecologic conditions are peculiar, and the soil has a characteristic flora in which scrub oak, pines, sweet fern, and a yellowish grass, locally known as "poverty grass," are prominent. This soil, however, is well adapted to the needs of tobacco. Its looseness makes the maintenance of good roads extremely difficult. Plate IX, *B* (p. 72), which is a view of the sand plain half a mile northwest of Tariffville, shows the very sandy road and the characteristic flora. In the middle distance is the corner of a "tent" used for raising shade-grown tobacco.

The ridge that separates the two sand plains owes its topographic prominence to the sheets of trap rock that underlie it. Most of East Granby is underlain by red sandstones and shales deposited during the Triassic period as sands and clays and subsequently indurated. The process of deposition was interrupted on three occasions by the

quiet volcanic extrusion of basic lava which spread out in broad sheets and eventually solidified as trap rock. South of Tariffville there are three trap sheets, of which the middle is the thickest (400 to 500 feet) and is therefore known as the "Main" sheet. Below it and separated from it by 300 to 1,000 feet of sandstone and shale is the "Anterior" trap sheet, which has a maximum thickness of 250 feet, and is so named because it outcrops on the front or face side of the cliff formed by the "Main" sheet. Above the "Main" sheet and separated from it by 1,000 to 1,200 feet of sandstone and shale is the "Posterior" trap sheet, 100 to 150 feet thick. The "Anterior" sheet thins out north of Tariffville and outcrops only in a few places.

At some time subsequent to their consolidation the sedimentary rocks and the associated trap rocks were broken into great blocks and tilted 15° or 20° E. Davis[1] has recognized and mapped one principal fault that bears about northeast and several minor faults that bear north or a little west of north. The ridge of Peak Mountain

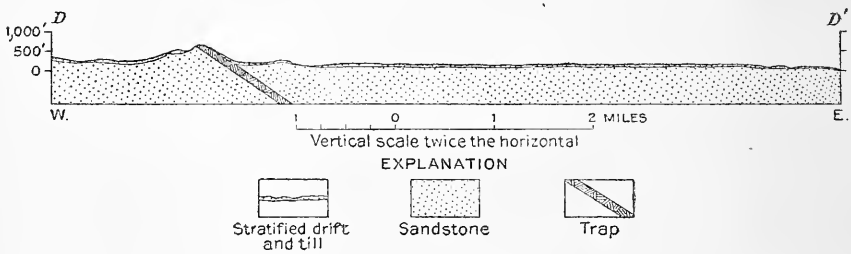


FIGURE 18.—Geologic section across East Granby and Suffield (section *D–D'* on Pl. V).

stands up because of the thick, resistant "Main" trap sheet that forms a bold westward-facing cliff. The ridge is broken by a gap about 200 feet deep where it is crossed by the Tariffville-Springfield Railroad. This gap is due to the major fault, which offsets a little the portions of the trap sheet to the northwest and southeast. The gorge of Farmington River at Tariffville was formed by deep erosion of a fault zone along which there was similar offsetting. This fault zone bears a little west of north. The block on the east was raised and moved southward so that the offset of the north part of the ridge relative to the south part was to the east. Plate X, *A*, shows the offset to the east or left of the nearer or north part of the ridge as seen from a point a mile north of Tariffville. The minor faults produce offsets on a smaller scale but of similar character. A section across East Granby and Suffield along the line *D–D'* on the map (Pl. V) is shown in figure 18, and the relation of the ridges and the plain to the underlying formation is there illustrated.

[1] Davis, W. M., The Triassic formation of Connecticut: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pl. 19, 1897.

A. OFFSET TRAP RIDGES NEAR TARIFFVILLE, CONN.

B. FLOWING WELL DRILLED IN SANDSTONE, EAST GRANBY, CONN.

The part of East Granby west of Peak Mountain and its southerly prolongation is drained by a branch of Salmon Brook, which joins Farmington River near Tariffville. In the southern part east of the ridge is a small area drained by short streams which empty directly into the Farmington. Most of the area east of the ridge, however, is drained by rather long northward-flowing streams that are tributary to Stony Brook (in Suffield), which empties into Connecticut River.

WATER-BEARING FORMATIONS.

Red sandstone.—Most of East Granby is underlain by red sandstone and shale of Triassic age. The beds have been tilted 15° or 20° E., and the rocks have been broken by the jarring, so that they are now traversed by many joints and large fractures. These openings form systems which tend to be either parallel or at right angles to the bedding. Water that has found its way into them from the overlying unconsolidated till or stratified drift may be recovered by means of drilled wells. The average depth of the 11 wells of this type that were visited in Suffield is 211 feet, and their average yield is 20 gallons a minute.

In much of the area a thick deposit of stratified drift mantles the sandstone. In places the stratified drift is as much as 100 feet thick, as shown by Mr. George Batytes's well (No. 5, Pl. IV), which went through 100 feet of sand, silt, and gravel before reaching the bedrock. In such places abundant supplies would probably be obtained in the stratified drift without drilling into the bedrock.

The drilled well of Mr. I. H. Griffin (No. 33, Pl. IV) is one of the few flowing wells in the State. It is probable that this well has cut one of a series of interconnecting fissures that are sealed in someway. The well is on the east slope of a low ridge, and considerable head is developed in the higher part of the ridge. The sealing below the well or to the east may be either due to the pinching out and narrowing of the fissures or to a blanket of impervious overlying till. The till on the hilltop must be pervious, else water could not enter the fissures. A view of the mouth of this well, showing its normal flow of 1½ gallons a minute, is given in Plate X, *B*.

Trap rock.—The trap sheets, which underlie narrow zones running north and south through East Granby, carry water in the same way as the sandstones and shales but rather less abundantly. Their topographic form is disadvantageous, as the bold cliffs allow the water to drain away rather readily. Mr. George E. Bidwell's well (No. 12, Pl. IV), for example, is 150 feet deep, but the water stands 75 feet below the mouth. In the other drilled wells in Suffield the average depth to water is only 22 feet, for there is little opportunity for escape of water from them.

Till.—Till forms a mantle over the higher portion of East Granby except for the areas where bedrock actually outcrops and the talus slopes below the trap cliffs. The principal till area includes Peak Mountain and its prolongation southward and a lower westward extension, but there are also two small till-covered ridges in the northeast corner of the town. The till is composed of all the rock débris plowed up and scraped along by the glacier. It was deposited as a blanket 20 to 30 feet thick in general and comprises a matrix of fine rock flour, clay, silt, and sand in which are embedded pebbles, cobbles, and boulders of great and small size. Because of the packing of the smaller particles into the interstices between the larger the till has only a moderate amount of pore space and the pores, moreover, are small. The deposit, then, is one of low porosity and low permeability. Nevertheless it has considerable value as a water-bearing formation and is able to store and slowly transmit moderate amounts of water. Wells dug in till are likely to obtain fairly reliable and fairly abundant supplies of water. Six such wells were visited in East Granby, and of these three were said to be nonfailing, but the dependability of the remaining three was not ascertained. The following table summarizes the measurements made on these wells:

Summary of wells dug in till in East Granby.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	27.9	20.5	18.6
Minimum	7.0	3.0	3.2
Average	18.4	10.3	8.1

Stratified drift.—The deposits of stratified drift, of which the origin and distribution in East Granby have been discussed above, is a far more efficient water-bearing formation than the till. It is composed in the main of the materials of the till reworked by running water. The grains have been sorted out according to size and deposited in different beds. The finer particles have been removed from the interstices of the coarser, so that there is not only a greater percentage of pore space, but the individual pores are larger and connect more freely. Large amounts of water may be recovered from the stratified drift by means of dug or driven wells. Mr. J. S. Dewey's well (No. 3, Pl. IV) was made the subject of a rough pumping test (see p. 41) which showed a yield of at least 5 gallons a minute. Measurements were made of 20 wells dug in stratified drift in East Granby in July and August, 1916. Of these 17 were said to be nonfailing and 2 were said to fail, but the reliability of the

other well was not ascertained. The data concerning the depths of these wells is summarized in the following table:

Summary of wells dug in stratified drift in East Granby.

	Total Depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	32.2	29.4	12.1
Minimum	5.4	3.1	1.5
Average	17.1	13.0	4.1

QUALITY OF GROUND WATER.

The results of two analyses and three assays of water collected in East Granby are given in the following table. The waters are all soft except No. 5, which is very soft, and No. 33, which is hard in comparison with other waters of this area. All the waters are low in mineral content except No. 33, which is moderately mineralized. All are classified as good for domestic use, but the large quantity of nitrate in No. 3 may be an evidence of contamination. No. 5 is classified as good for use in boilers, but the rest are classed as fair because they contain considerable amounts of scale-forming constituents. The waters are calcium-carbonate in type except No. 8, in which chloride is the dominant acid radicle.

Chemical composition and classification of ground waters in East Granby.[a]

[Parts per million. Analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. IV.]

	Analyses.[b]		Assays.[c]		
	[d] 3	[e] 5	[e] 8	[f] 26	[f] 33
Silica (SiO_2)	13	18			
Iron (Fe)	1.4	.68	Trace.	0.47	0.08
Calcium (Ca)	27	14			
Magnesium (Mg)	2.9	2.6			
Sodium and potassium (Na+K) [g]	5.7	7.0	5	7	4
Carbonate radicle (CO_3)	.0	.0	.0	.0	12
Bicarbonate radicle (HCO_3)	45	45	36	104	105
Sulphate radicle (SO_4)	23	12	12	8.0	35
Chloride radicle (Cl)	11	3.4	27	4.8	2.0
Nitrate radicle (NO_3)	19	8.2			
Total dissolved solids at 180° C	150	[h] 88	[g] 120	[g] 130	[g] 190
Total hardness as $CaCO_3$	80	46	70	87	137
Scale-forming constituents [g]	98	64	95	110	160
Foaming constituents [g]	15	19	10	20	10
Chemical character	Ca-CO_3	Ca-CO_3	Ca-Cl	Ca-CO_3	Ca-CO_3
Probability of corrosion [i]	(?)	(?)	(?)	(?)	(?)
Quality for boiler use	Fair.	Good.	Fair.	Fair.	Fair.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 130-131.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Collected Mar. 19, 1918.
[e] Collected Nov. 18, 1916.
[f] Collected Dec. 6, 1916.
[g] Computed.
[h] Total solids by summation.
[i] Based on computed quantity; (?)=corrosion uncertain.

RECORDS OF WELLS AND SPRINGS.

Only one spring was visited in East Granby. It is plotted on the map as No. 27 and is situated at the foot of a terrace scarp. The yield is large, and the water is pumped to a house.

Wells dug in till in East Granby.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above level.	Total depth.	Depth to water in well.	Depth of water.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
10	....	Slope......	270	14.8	11.6	3.2	Windlass rig and house pump.	Unfailing.
13	J. W. Bidwell...	.....do.....	275	25.8	13.7	12.1	Chain pump......	Do.
15	....	Plain......	185	9.8	6.0	3.8	.....do............	
23	....	Ridge......	245	27.9	20.5	7.4	Windlass rig......	
24	....	Slope......	240	7	3	4	House pump......	Do.
25	....	Terrace....	250	25.4	6.8	18.6	Windlass rig......	

Wells dug in stratified drift in East Granby.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Terrace..	270	17.0	15.5	1.5	House pump......	Nonfailing.
2	....	...do.....	195	24.0	21.5	2.5	Deep-well pump..	Nonfailing. In rock 2 feet.
3	J. S. Dewey....	Slope....	200	24.9	21.8	3.7	(a)	Nonfailing. For analysis see p. 129.
8	Peter Bradley...	Plain....	150	5.4	3.1	2.3	Windlass rig......	Nonfailing. For assay see p. 129.
9	....	Slope....	150	13.8	8.5	5.3	Chain pump......	Fails.
14	....	Plain....	170	12.4	8.9	3.5	.....do............	Nonfailing.
16	....	Slope....	195	24.0	20.1	3.9	Windlass rig......	
17	....	.....do...	195	14.6	11.5	3.1	Chain pump......	Abandoned.[b]
18	....	Ridge....	205	26.0	17.1	8.9	Windmill..........	Nonfailing.
19	....	Plain....	195	7.0	4.7	2.3	Chain pump......	Do.
20	....	Swale....	200	14.7	6.4	8.3	.....do............	Do.
21	....	Slope....	190	18.0	14.0	4.0	Deep-well pump..	Do.
22	....	Ridge....	210	14.8	13.1	1.7	Two-bucket rig...	Do.
28	....	Plain....	205	32.8	29.4	3.4	.....do............	Nonfailing. Temperature, 55° F.
29	Griffin-Newberger Tobacco Co.	.....do...	195	8.7	6.4	2.3	Windlass rig and house pump.	Nonfailing.
30	....	Slope....	180	17.3	12.6	4.7	No rig............	Fails.
31	....	Plain....	185	22.0	9.9	12.1	Windlass rig......	Nonfailing.
32	H. Russell.....	.....do...	160	11.1	7.7	3.4	Sweep rig.........	Do.
34	....	.....do...	195	16.6	14.3	2.3	Deep-well pump..	Do.
35	....	.....do...	185	17.4	14.6	2.8	Two-bucket rig...	Do.

a Pumping test made on this well. (See p. 41.)
b Formerly this well did not fail. The recent construction of a railroad cut 10 feet north and 10 feet lower has interfered with its supply.

Drilled wells in East Granby.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water in well.	Diameter.	Yield per minute.	Kind of rock.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Gallons.*		
4	J. S. Dewey	Slope	210	402	37	30	6	19	Sandstone	(*a*)
5	George Batytes	Terrace	190	118	100		6	3	do	For analysis see p. 129.
6	Connecticut Tobacco Corp.	Plain	170	360		30		+30	do	
7	William Landroth.	Terrace	160	110	60		6	8	do	(*b*)
11		Slope	415	85					Trap	Water very hard.
12	Geo. E. Bidwell	do	385	150		75	6	11	do	
26	L. H. Seymour	do	215	152	10	5	6	19	Trap and sandstone.	For assay see p. 129. *c*
33	I. H. Griffin	do	180	125			6	(*d*)	Sandstone	For assay see p. 129.

a Water enough for drilling at 40 feet; gain of only 2 gallons a minute from 200 to 400 foot depth.
b Drilled through 10 feet of sand, 4 or 5 feet of gravel, 45 feet of "blue clay," and 2 feet of "trap rock," and the rest in sandstone.
c Drilled through 10 feet of soil and 10 feet of trap rock and rest in sandstone. Windmill and gravity tank.
d Well flows with a head of about 3 feet and with the outlet depressed 18 inches; it flows $1\frac{1}{2}$ gallons a minute. Can pump 50 gallons a minute.

ENFIELD.

AREA, POPULATION, AND INDUSTRIES.

Enfield is a manufacturing and farming town in the northeast corner of Hartford County. It is bounded on the north by Massachusetts, on the east by Somers, in Tolland County, and on the west by Connecticut River. The town covers about 34 square miles, of which 13 square miles, or about 40 per cent, is wooded. A strip $1\frac{1}{2}$ miles wide along the Connecticut is in the main cleared, but woodlands are uniformly distributed throughout the rest of the town. Thompsonville, on Connecticut River, $1\frac{1}{2}$ miles south of the Massachusetts boundary, is the principal settlement. The village of Enfield is strung out for $1\frac{1}{2}$ miles along Enfield Street, which follows the crest of the ridge south from Thompsonville. Hazardville and Scitico are small settlements in the eastern part of the town. There are post offices and stores at all the places. The town has about 75 miles of road, exclusive of the streets of Thompsonville and including $7\frac{1}{2}$ miles of the State trunk-line road from Hartford to Springfield. The Hartford division of the New York, New Haven & Hartford Railroad follows the west boundary and has stations at Thompsonville and Enfield Bridge. The Springfield division of the same company runs north and south through the eastern part of the town and has stations at Scitico and Shaker Station. The East Side line of the Hartford & Springfield Street Railway Co. runs through Enfield and Thompsonville, and the Somers branch leaves the main line a

little south of Thompsonville and runs through Hazardville and Scitico to Somerville and Somers.

Enfield was named and granted by Massachusetts in 1683 and annexed to Connecticut in 1749. Since then there has been no change in its extent or organization. In 1910 the population was 9,719, an increase of 3,020 over the population of 1900. The density is 284 inhabitants to the square mile, but most of the population is concentrated in Thompsonville, and most of the area is much more sparsely populated. The following table shows the changes in population since 1756:

Population of Enfield, 1756 to 1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1756	1,050		1840	2,648	+24
1774	1,360	+30	1850	4,460	+68
1782	1,562	+15	1860	4,997	+12
1790	1,800	+15	1870	6,322	+27
1800	1,761	− 2	1880	6,755	+ 7
1810	1,846	+ 5	1890	7,199	+ 7
1820	2,065	+12	1900	6,699	− 7
1830	2,129	+ 3	1910	9,719	+43

[a] Connecticut Register and Manual, 1919, p. 638.

There has been in general an increase in each census period. The manufacture of carpets was begun at Thompsonville about 1830 and the manufacture of gunpowder at Hazardville a few years later. The growth in population has been dependent in large part upon the prosperity of these industries. The decrease of population from 1890 to 1900 was probably due to the abandonment of the powder factory at Hazardville. Thompsonville may continue to grow steadily, but no great increase is to be expected in the rest of the town.

The principal industries of Enfield are the manufacture of carpets and undertakers' supplies and agriculture, which is confined chiefly to the raising of wrapper and binder tobacco.

SURFACE FEATURES AND GEOLOGIC STRUCTURE.

Most of Enfield lies on a sand plain, 120 feet above sea level at the south boundary and 200 feet at the north. Along the east boundary till-covered slopes rise to a maximum elevation of 400 feet above sea level. The plain is bounded on the west in part by a ridge 140 to 180 feet high, the west slope of which extends inland to the river and in others flattens to a terrace 60 to 80 feet above sea level. The river is about 25 feet above sea level at the southeast corner of the town. The total range in elevation is about 375 feet.

The bedrock of Enfield comprises the red sandstones, shales, and conglomerate of the upper part of the Triassic. They were originally deposited as sands, clays, and gravels, but became cemented and consolidated. Subsequently they were broken into great blocks and tilted 15° or 20° E. Their history since has been solely one

of erosion. Prior to the glacial epoch the Connecticut had a channel east of the Enfield Street ridge, as is indicated by the well of Mr. Richard Smyth (No. 31. Pl. IV). This well is 418 feet deep, but reached bedrock only at a depth of 236 feet. As the mouth of the well is about 120 feet above sea level, the bedrock at this point is over 100 feet below sea level. The most probable explanation of these facts is that formerly the land stood about 150 feet higher than now, and that Connecticut River cut a channel which passed this point. During the later part of the glacial epoch, as the ice sheet was receding from this region, many streams of melt water issued from its front carrying much débris, which was deposited in the main in the broad central valley of Connecticut River, forming broad outwash plains. These deposits filled and blocked the old channel and diverted the river into its present course. The youth of this new channel from Thompsonville to Windsor Locks is shown by two facts—that the stream is not yet worn to grade and still has many small rapids and riffles, and that the banks are in large part low, fresh cliffs of sandstone. Moreover, there are no flood plains in this narrow portion of the valley as there are in the broader portions to the north and south.

The outwash plain is in general well preserved, but Scantic River has cut in it a valley 80 to 100 feet deep and a quarter to three-quarters of a mile wide. The floor of this valley is flat and in part swampy.

The till-covered slopes along the east boundary owe their elevation to the resistance of the underlying sandstone. The boundary between the till of the slopes and the stratified drift of the plain is about 200 feet above sea level.

The southeastern part of Enfield is drained by Scantic River and its tributaries. The Scantic enters the town from the east near Scitico and flows west to Hazardville, and then turns south into East Windsor. The southwestern part of Enfield is drained by short brooks that empty into Connecticut River. Grape Brook and Freshwater Brook drain the northern half of the town. In comparison with towns in which till is the dominant surface material, there are few brooks in Enfield, because the water that falls as rain soaks readily into the porous soil, becomes part of the ground-water body, and reaches the main streams by percolation through the ground rather than by flowing in surface streams.

WATER-BEARING FORMATIONS.

Red sandstone.—Red sandstone and associated red shales and conglomerates form the bedrock of Enfield. They crop out in a number of places along Connecticut River and on the ridge just east of the river, and there are a few outcrops on the till-covered slopes along

the east boundary of the town. These rocks are cut by numerous joints and fissures formed by the jarring and crushing incident to their tilting. There are probably zones in the sandstone that are somewhat porous, but they do not constitute an important source of ground water. The joints and fractures form a maze of interconnecting channels into which water works its way from the saturated basal portions of the overlying mantle rock. This water may be recovered by means of drilled wells. A drill hole at any point will probably cut one or more fissures and procure a satisfactory supply of water. Data were obtained concerning 13 such wells in Enfield and are summarized in the following table.

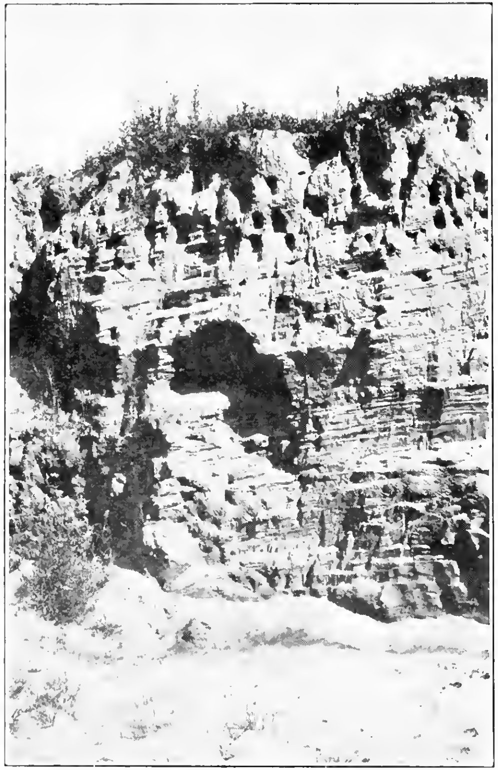
Summary of drilled wells in Enfield.

	Total depth.	Depth to rock.	Depth to water.	Yield per minute.
	Feet.	*Feet.*	*Feet.*	*Gallons.*
Maximum	487	236	90	170
Minimum	38	25	8	22
Average	179	55	27	52

The drilled well of Dr. Vail (No. 14, Pl. IV) has a depth of 487 feet, of which 450 feet is in rock. The well yields 50 gallons a minute, but the water stands 90 feet below the surface. This is presumably because the well is situated near the crest of a ridge from which the water drains with considerable facility.

Till.—The slopes in the eastern part of Enfield are covered with a mantle of till, which is, in general, 20 to 30 feet thick. It is a dense mixture of glacial débris and consists of a well-compacted matrix of fine rock flour, clay, silt, and sand, in which larger fragments are embedded. It is able to absorb and transmit moderate amounts of water that falls on it as rain and yields fairly abundant and dependable supplies of water to wells dug in it. Three such wells were visited in Enfield and all are said never to fail.

Stratified drift.—The bedrock of Enfield, except the hills in the eastern part, is covered by stratified drift. The evidence of the drilled wells in the town is that the thickness of the stratified drift ranges from 25 to 236 feet, the average being 55 feet. Inasmuch as one of these wells was sunk through an unusually great thickness of stratified drift, this average may be too great. Probably a better estimate would be 35 or 40 feet. In Thompsonville and on the Enfield Street ridge there is only a thin mantle. In excavations at various points there was only 3 or 4 feet of stratified drift, and below it there was either till or red sandstone. (See Pl. XI, *B*.) The stratified drift is of aqueous origin and comprises the well-washed, reworked constituents of the till, together with minor amounts of débris formed by the erosion of firm rocks. For the



A. SAND PIT IN STRATIFIED DRIFT, THOMPSONVILLE, ENFIELD, CONN.

B. STRATIFIED DRIFT OVERLYING TILL, THOMPSONVILLE, ENFIELD, CONN.

most part it consists of clean sand, such as is shown in Plate XI, *A*, which is a view of a sand pit in the northern part of Thompsonville belonging to O. H. Pease. The sandy portions of the stratified drift and the less abundant gravels were deposited by streams that issued from the front of the glacier during its recession. The climate at the end of the glacial epoch was such that great volumes of ice were melted and gave rise to vigorous streams. In the lower lying portions of Connecticut, and especially in the valleys of Connecticut and Farmington rivers, these streams deposited extensive plains known as outwash plains. During part of the time there were lakes in front or south of the ice front and in them very fine grained silt and clay were deposited. These clays are the raw material for the brick industry of the Connecticut Valley, and have been worked in Thompsonville. They yield no significant amount of water, but may be of importance in restricting and concentrating the flow of ground water in other more porous horizons.

The sands and gravels of the stratified drift are excellent bearers of ground water, as they are not only highly porous but also very permeable. The effect of the washing has been to leave in each bed only grains of a size, and this results in high porosity. The grains themselves are relatively coarse, so that the interstices between them are large and they transmit water readily. The absorption of rain water and its transmission are the same in manner as in the till, but on a more vigorous scale, so that much more water may be recovered. Plate XI, *B*, shows about 5 feet of stratified drift overlying about 7 feet of till in an excavation for a building in Thompsonville. The sand and gravel are quite dry, because the water has drained from their coarse pores, whereas the till is still moist, because its fine pores have retained much of their water. The light band at the top of the till is quite as moist as the dark part below. Its lighter color is due not to dryness but to the fact that it was exposed to weathering and oxidation before it was covered over by the stratified drift.

Measurements were made of 48 wells dug in stratified drift in Enfield in August, 1916. The reliability of all but 10 was ascertained; 34 were said never to fail and 4 were said to fail. The data concerning the depths of these wells are summarized in the following table:

Summary of wells dug in stratified drift in Enfield.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	27.3	24.5	16.2
Minimum	7.3	3.2	1.4
Average	14.3	9.0	5.3

Wherever the ground surface has been cut low enough, as for example along streams, the water table is reached, and springs or seeps are found. Along the steep slope that bounds the flood plain of Scantic River there are numerous such springs, some of which have large yields.

QUALITY OF GROUND WATER.

The subjoined table gives the results of two analyses and four assays of samples of ground waters collected in the town of Enfield. The waters are low in mineral content except Nos. 31 and 29, which are moderately mineralized. Nos. 30 and 52 are very soft waters, Nos. 1 and 53 are soft waters, and Nos. 31 and 29 are hard waters for this area. All are classified as good so far as their chemical character may affect their suitability for domestic use. Nos. 31, 1, and 29 are classified as fair for boiler use because there is in each a considerable amount of scale-forming ingredients. The rest are so low in scale-forming and foaming ingredients that they are considered good for boiler use, although the probability of corrosion is uncertain and will be determined by actual operating conditions.

Chemical composition and classification of ground waters in Enfield.[a]

[Parts per million. Collected November 17, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. IV.]

	Analyses.[b]		Assays.[c]			
	30	31	1	29	52	53
Silica (SiO_2)	17	27				
Iron (Fe)	.04	.09	0.11	Trace.	Trace.	0.20
Calcium (Ca)	9.7	52				
Magnesium (Mg)	2.6	8.0				
Sodium and potassium (Na+K) [d]	13	30	Trace.	42	7	13
Carbonate radicle (CO_3)	.0	4.8	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	40	98	22	105	35	49
Sulphate radicle (SO_4)	17	128	29	36	7.0	27
Chloride radicle (Cl)	3.9	3.8	19	78	3.6	11
Nitrate radicle (NO_3)	7.9	Trace.				
Total dissolved solids at 180° C	94	303	[d] 120	[d] 300	[d] 71	[d] 120
Total hardness as $CaCO_3$	[d] 35	[d] 163	86	151	28	58
Scale-forming constituents [d]	50	190	110	180	55	85
Foaming constituents [d]	35	81	([e])	110	20	40
Chemical character	Na-CO_3	Ca-SO_4	Ca-SO_4	Ca-Cl	Ca-CO_3	Ca-CO_3
Probability of corrosion[f]	(?)	(?)	(?)	(?)	N	(?)
Quality for boiler use	Good.	Fair.	Fair.	Fair.	Good.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 137–139
[b] For methods used in analyses and accuracy of results see pp. 52–60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52–60.
[d] Computed.
[e] Less than 10 parts per million.
[f] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

PUBLIC WATER SUPPLIES.

Water has been supplied to the residents of Thompsonville and to a few in Suffield, on the west bank of Connecticut River, by the Thompsonville Water Co. since 1885. Water is obtained from

springs in the valley of Grape Brook in the northern part of the town and is run into two reservoirs of 1,000,000 and 8,000,000 gallons capacity, respectively. Steam-driven reciprocating pumps, with a capacity of 2,000,000 gallons a day, deliver the water to an elevated tank with a capacity of 500,000 gallons on the ridge at the north end of Enfield Street. The water is distributed by gravity under a pressure of about 70 pounds to the square inch, through 34 miles of main pipe to 163 fire hydrants and 1,386 service taps. The average daily consumption by the 9,300 people served is about 423,000 gallons.[1] Mr. Walter P. Schwabe, the manager, says that the introduction of meters has reduced the consumption at least 25 per cent. It is planned to replace the present pumping equipment with an electrically driven centrifugal pump with a capacity of 1,000 gallons a minute. The consumption now is almost as great as the yield of the springs. As Enfield is relatively low and level it will very probably be necessary to develop a ground-water supply, which could readily be done by means of batteries of wells driven across one of the brook valleys in the northern part of the town.

Since 1892 the Hazardville Water Co. has served residents of Hazardville and Scitico. Water is obtained from springs near Hazardville and from a well 8 inches in diameter drilled in the sandstone. A cylinder pump, 48 by 6 inches, at a depth of 150 feet in the well is driven by a steam engine and delivers 10,000 gallons an hour to two elevated tanks which have a capacity of 30,000 and 50,000 gallons. From them the water is distributed by gravity under a pressure of 25 to 40 pounds to the square inch through 4 miles of main pipe to 18 fire hydrants and 222 service taps. There are 154 customers in Hazardville and 36 in Scitico, and the average daily consumption by the 1,100 people supplied is 35,600 gallons.[1]

RECORDS OF WELLS AND SPRINGS.

Wells dug in till in Enfield.

No. on Pl. IV.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
		Feet.	*Feet.*	*Feet.*	*Feet.*		
51	Plain.......	205	15.	11.	4.	....	Nonfailing.
67	Hill........	260	18.2	8.2	10.	No rig.........	Nonfailing. Abandoned.
68	.....do......	260	23.8	11.4	12.3	Chain pump..	Nonfailing.

[1] Rept. Connecticut Public Utilities Commission, 1917.

Wells dug in stratified drift in Enfield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	C. E. Pease	Plain	95	18.4	15.8	2.6	Windlass rig	Nonfailing. For assay see p. 136.
2		do	105	13.5	8.8	4.7	Chain pump	Nonfailing.
3		do	125	10.2	6.3	3.9	do	Do.
4		Slope	160	11.2	5.8	5.4	Air-pressure system.	Do.
5	H. W. Neelans	Plain	190	12.8	7.7	5.1	Chain pump	Do.
6	Edw. C. Bacon	Terrace	160	13.1	10.9	2.2	Pitcher pump	Fails.
9		Plain	160	12.4	8.9	3.5	Chain pump	Nonfailing.
10		Slope	145	11.8	8.7	3.1	House pump	Do.
11		Plain	165	18.5	11.1	7.4	Chain pump	Do.
12		do	165	13.4	9.2	4.2	Chain pump and house pump.	Do.
13		do	165	13.0	8.4	4.6	One-bucket rig	Fails.
15		Hill	180	27.3	20.1	7.2	Wheel and axle rig.	Nonfailing.
16		do	150	21.0	9.1	11.9	Chain pump	Do.
17		Plain	145	21.7	11.7	10.0	Windlass rig	Do.
18	Wm. Oliver	do	120	23.3	7.1	16.2		Nonfailing. Abandoned.
19		Hill	145	13.2	5.7	7.5	Sweep rig	Nonfailing.
20	F. J. Pease	do	145	17.6	9.6	8.0	No rig	Nonfailing. Abandoned.
21		Plain	110	10.6	6.8	3.8	Chain pump	
22		Slope	145	15.1	6.9	8.2	do	Nonfailing.
23		Plain	105	22.9	8.5	14.4	do	
24	Leon Abbe	Hill	145	14.6	7.2	7.4	No rig	Nonfailing. Abandoned.
25		Terrace	100	10.7	7.1	3.6	House pump	Nonfailing.
26		Slope	145	12.1	7.0	5.1	Chain pump	Do.
27		do	145	16.2	8.8	7.4	do	Do.
28		Plain	155	13.4	9.7	3.7	do	
29	R. E. Parson	do	150	13.6	8.0	5.6	House pump	Nonfailing. For assay see p. 136.
30	M. W. Dunne	do	140	8.2	4.9	3.3	Chain pump	Nonfailing. For analysis see p. 136.
32		Terrace	140	15.9	13.7	2.2	Windlass rig	Nonfailing.
33		Plain	145	11.3	8.2	3.1	Chain pump	Do.
34		do	135	9.0	6.7	2.3	Windlass rig	Do.
35		do	130	9.1	7.0	2.1	do	
36		do	135	12.9	11.5	1.4	do	Do.
38		do	130	11.4	7.1	4.3	Chain pump	Do.
39		do	130	11.5	7.9	3.6	do	Do.
40		do	125	10.1	4.0	6.1	do	
41		do	115	16.5	12.0	4.5	do	Do.
42		do	125	7.3	4.5	2.8	do	
43		Terrace	120	9.8	5.2	4.6	do	Do.
44		Plain	125	11.9	6.4	5.5	do	
45		do	105	12.0	7.4	4.6	do	Do.
46		do	165	24.3	19.0	5.3	do	
49		do	185	16.0	8.2	7.8	do	
50		do	175	14.8	9.1	5.7	House pump	Do.
53	Richard Bogan	Terrace	175	15.9	12.0	3.9	Chain pump	Fails. For assay see p. 136.
54		Slope	160	26.4	24.5	1.9	Windlass	Fails.
56		do	135	11.2	5.3	5.9	Gravity system	Nonfailing.
58		do	95	8.1	4.7	3.4	Chain pump	Do.
66		do	190	11.8	9.5	2.3	Windlass rig	

Drilled wells in Enfield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water in well.	Diameter.	Yield per minute.	Kind of rock.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*In.*	*Gals.*		
7	R. E. Davidson.	Plain...	165	100	36	8	6	25	Sandstone.	Temperature 50° F.
8	F. W. Olmsted..	...do....	165	147	40	14	6	22	...do......	
14	Dr. Thornton Vail.	Ridge...	185	487	37	90	......	50	...do......	Pumped by air lift.
31	Richard Smith.	Plain...	125	418	236	40	6	40	...do......	For analysis see p. 136.[a]
47	....	...do....	185	38	34	28	6	......	...do......	
48	Hazardville Water Co.	...do....	185	257	25	16	8	170	...do......	
59	H. E. Pierce....	...do....	135	82	38	20	6	36	...do......	
60	Samuel Neelon..	Slope...	100	70	44	20	6	48	...do......	
61	Olm Olmsted...	...do....	90	144	28	24	6	60	...do......	
62	David Golden...	...do....	110	112	69	27	6	45	...do......	
63	Joseph Rostek...	Plain...	145	276	30	20	6	42	...do......	
64	H. E. Holbrook.	Slope...	190	120	......	18	6	45	...do......	
69	Fred Farber....	...do....	95	75	51	26	6	38	...do......	

[a] Only 1 quart a minute at 380 feet, 18 gallons a minute at 400 feet, and full flow of 40 gallons a minute at 418 feet.

Springs in Enfield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Temperature.	Yield per minute.	Remarks.
			Feet.	*°F.*	*Gallons.*	
37	....	Swale.........	80	50(?)	....	Pumped to tanks.
52	E. P. Terry...	......do........	155	50	Large...	Pumped by water wheel to tank. Formerly supplied village of Scitico. Water from stratified drift. For assay see p. 136.
55	....	Foot of terrace.	140	50	1	
57	....	Foot of slope..	80	63	....	
65	....	By brook.....	145	50	100(?)	

SUFFIELD.

AREA, POPULATION, AND INDUSTRIES.

Suffield is a large farming town near the middle of the north boundary of Hartford County, and is bounded on the north by Massachusetts and on the east by Connecticut River. The town has an area of 43 square miles, of which 13 square miles, or 30 per cent, is wooded. The woodlands are in small or moderate-sized patches that are well distributed, though they are a little more abundant on the hills in the western part of the town. There are 60 miles of road in the town, including 5 miles of the Hartford-Springfield trunk line and 5 miles of road that is in part maintained by the State. The West Side trolley line of the Hartford & Springfield Street Railway Co. runs through Suffield. A branch of the Hartford division of the New York, New Haven & Hartford Railroad joins the main line at Windsor Locks. The Springfield branch of the Central New England Railway crosses the town from north to south

and has stations at West Suffield and Sheldon Street. The Northampton division (Canal Road) of the New York, New Haven & Hartford Railroad runs across the west corner of Suffield, and its station at Congamond is used by the residents of that part of the town.

The principal settlement is Suffield, a village spread out along 2 miles of the main highway between Hartford and Springfield. West Suffield is a smaller village that lies 3 miles to the west. There are stores, hotels, and a post office at each of these places.

Suffield was incorporated by Massachusetts in 1674 and was annexed to Connecticut in 1749. Since then there has been no change in its organization or territorial extent. In 1910 the population was 3,841, an increase of 320, or 9 per cent, over the population of 1900, and equivalent to a density of population of 89 inhabitants to the square mile. The following table shows the changes in population since the annexation to Connecticut:

Population of Suffield, 1756–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1756	1,438	....	1840	2,669	−1
1774	2,017	40	1850	2,962	11
1782	2,301	14	1860	3,260	10
1790	2,467	7	1870	3,277	1
1800	2,686	5	1880	3,225	−2
1810	2,680	0	1890	3,169	−2
1820	2,681	0	1900	3,521	11
1830	2,690	0	1910	3,841	9

[a] Connecticut Register and Manual, 1919, p. 641.

During most of the nineteenth century the population changed very little, but the last two censuses show some increase, due, presumably, to the culture of leaf tobacco for cigar wrappers and binders and to the establishment of manufactures of cigars, which are the principal industries of the town.

SURFACE FEATURES AND GEOLOGIC STRUCTURE.

Most of Suffield has a gently undulating surface, interrupted by two high trap ridges and by rather broad valleys. The plain character is best developed in the northwest corner of the town, where it has an elevation of 240 to 280 feet above sea level, and along the south boundary, where it ranges from 120 to 160 feet in elevation. The eastern edge of the plain slopes gently eastward for about a mile but pitches sharply down to Connecticut River, making low cliffs in places. The northward extension of the trap ridges of Peak Mountain has its highest point a mile north of the East Granby town line, where it is 660 feet above sea level. As Connecticut River at the

southeast corner of the town is only about 20 feet above sea level, the area has a range in elevation of 640 feet.

During the Triassic period central Connecticut was a great valley in which a thick series of sediments, sands, silt, clay, and gravel was deposited. These sediments were hardened and cemented to form the red sandstone, shale, and conglomerate that crop out at many places. The process of deposition was interrupted three times by the quiet pouring out over the valley floor of lava that on solidifying became the trap sills characteristic of the region. The relation of these sheets and the sandstones with which they are intercalated is shown in the following table, which is quoted from Davis:[1]

Section of the Triassic of Connecticut.

	Feet.
Upper sandstones	3,500
Posterior trap sheet	100–150
Posterior shales and shaly sandstones	1,200
Main trap sheet	400–500
Anterior shales and shaly sandstones	300–1,000
Anterior trap sheet	0–250
Lower sandstones	5,000–6,500

In the present discussion the name "sandstone" is frequently used to mean all the Triassic sedimentary rocks, whether shale, conglomerate, limestone, or true sandstone. In places there are trap sheets and dikes that were forced into the sediments after they had been deposited.

Subsequent to their consolidation these rocks were broken into great fault blocks and tilted to the east. Erosion has cut away the softer sediments and left the trap sheets exposed so that they form prominent hills and ridges. The ridge of which Peak Mountain is a part is underlain by and owes its topographic prominence to the extrusive trap sheets. Manitick Mountain in the west part of Suffield is similarly dependent on one of the trap masses intruded into the sediments after their deposition.

Just before the advance of the great ice sheet in the glacial epoch this territory was somewhat more rugged than it now is. There were the two trap ridges and six or seven ridges formed by resistant zones in the sandstone, all running north and south. The position of the sandstone ridges is roughly the same as the north-south strips of till shown on the geologic map (Pl. V). The ice sheet as it moved over these hills broke and ground off the projecting points and wore away the whole surface more or less. The resulting débris, which is called till, was plastered rather uniformly over the whole region, but especially in the depressions, thus reducing the ruggedness of the

[1] Davis, W. M., The Triassic formation of Connecticut: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 2, pp. 28 and 29, 1898.

topography. This process was still further continued by the deposition of stratified drift in the valleys by ice-borne streams. These streams carried much sediment derived in part from the ice and in part from reworking of the till. As these streams were slowed up a little beyond the front of the glacier they dropped their loads and so built up the stratified drift plains that form much of the floor of the valley of central Connecticut. The till-covered sandstone hills were in part buried so that now only their tops show. In some a large part of the bulk is above the stratified drift, as, for example, the hill on which the village of Suffield is situated and which extends north to Buck Hill, but of others, such as those south of West Suffield, only a little protrudes. It is quite possible that some till-covered hills are completely buried and may eventually be exposed if erosion removes the stratified drift. West of Peak Mountain the elevation of the boundary between the stratified drift and the till ranges from 240 to 280 feet above sea level, and on the east from 100 to 220 feet, being lowest near Connecticut River. The greater height west of Peak Mountain is presumably due to the fact that this ridge dammed the streams from the glacier and so raised the level to which they worked. Along Connecticut River, between Thompsonville and King Island, are rather large areas of till, which were probably formerly covered by stratified drift, but have been exposed by erosion. This portion of the Connecticut flows in a relatively new channel, and erosion along and near it has been great. The relation of the topography to the different rocks is shown in the section (fig. 18, p. 126), the position of which is indicated by the line *D–D′* on the maps (Pls. IV and V).

Some of the part of Suffield west of Peak Mountain ridge drains to Salmon Brook in Granby and so is tributary to Farmington River, and some of it drains to Congamond Pond and is tributary to Westfield River. Most of the town, however, is drained by Stony Brook, which joins Connecticut River near the southeast corner of the town. About 6 square miles is drained by short brooks that empty directly into the Connecticut.

WATER-BEARING FORMATIONS.

Trap rock.—The trap rocks of Suffield do not constitute an important source of ground water. They do contain some water in joints and fissures, but the hardness of the rock makes its recovery difficult and expensive. Moreover, the resistance of the trap to erosion leaves it in unfavorable topographic forms, so that much of the water drains away and many of the fissures are dry.

Sandstone.—Considerable amounts of water are recovered by means of wells drilled in the red sandstone in Suffield. The unconsolidated soil above it absorbs a good deal of rain and snow water and transmits it in part to the joints and fissures made in the bedrock by the

crushing and jostling incident to tilting and faulting. The fissures tend to form systems of parallel fissures, which are in general roughly parallel to the bedding planes or at right angles to them. The rocks, then, are cut by an intricate network of interconnecting fissures from which water may be recovered by drilled wells. Some of the coarser sandstone beds may contain water in the interstices between the grains, but this is not an important source of supply. It is highly probable that a hole drilled at any point will cut one or more water-bearing fissures within a reasonable distance and so obtain a satisfactory supply. Twenty-six such wells were visited in Suffield in August, 1916. The data collected concerning them are summarized in the following table:

Summary of drilled wells in Suffield.

	Total depth.	Depth to rock.	Depth to water in well.	Yield per minute.
	Feet.	*Feet.*	*Feet.*	*Gallons.*
Maximum	288	100	90	135
Minimum	63	1	0	6
Average	161	44	25	39

Till.—About 13 square miles or 30 per cent of the total area of Suffield is mantled with till. There are a few large patches and a number of small ones. Their distribution has been discussed above and is also shown on the geologic map (Pl. V). The till was deposited by the plastering action of the glacier and consists of all the débris of the ice, the smaller particles forming a matrix in which the larger are embedded. As the whole mass is tightly packed and the smaller particles are fitted into the chinks between the larger, the total porosity and the size of the individual pores are small. A fair proportion of the rain that falls on the till is absorbed and slowly transmitted. Wells dug in till are in general satisfactory, especially if they are so deep as to penetrate the saturated zone just over the bedrock, or if they happen to cut one of the masses of partly washed and sorted material that exist in some places in the till. Measurements were made of 35 wells dug in till in Suffield. The dependability of 27 of these wells was ascertained; 19 were said to never fail and 8 were said to fail. The data collected concerning the depths of these 35 wells are summarized in the following table:

Summary of wells dug in till in Suffield.

	Total depth.	Depth to water.	Depth of of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	46.8	30.9	15.9
Minimum	7.2	4.4	2.6
Average	22.3	12.9	9.4

Stratified drift.—The mantle rock of the lower parts of Suffield is stratified drift, which is composed of the reworked material of the till plus some débris derived from the erosion of the bedrock. Streams issuing from the glacier during its recession had high velocities and bore much débris, but they were soon slowed up and forced to deposit much of their load. Thus beds and lenses of sand and gravel were deposited near the glacier, whereas the finer and lighter débris was carried farther away and ultimately deposited as clay and silt. By this process the débris was sorted into beds in each of which the grains are of uniform size, and the finer grains were eliminated from the interstices between the larger. The stratified drift is therefore not only high in porosity but has relatively large and open pores. For these two reasons it is an excellent water-bearing formation except where it has an unfavorable topographic form, as on terraces from which water may drain readily. Measurements were made of 44 wells dug in stratified drift. Of these wells 23 were said to never fail and 17 were said to fail; the reliability of the remaining 4 was not ascertained. The information collected concerning the depths of the 44 wells is summarized in the following table:

Summary of wells dug in stratified drift in Suffield.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	34	27	16.6
Minimum	8.3	5.2	1.7
Average	17.8	11.9	5.9

QUALITY OF GROUND WATER.

The accompanying table gives the results of two analyses and four assays of samples of ground water collected in the town of Suffield. These waters are moderately mineralized except No. 35, which is low in mineral content, and No. 99, which is high. No. 35 is a very soft water; No. 32 is soft; Nos. 36, 93, and 97 are hard for this section of the country; and No. 99 is very hard. Nos. 36 and 99 are considered to be poor for use in boilers because they contain excessive amounts of scale-forming ingredients. Nos. 93 and 97 contain rather less scale-forming ingredients and would probably be fair for boiler use. Nos. 32 and 35 are good for boiler use. So far as their mineral character is concerned, all the waters are acceptable for domestic use except No. 99, which is very hard. Nos.

93, 97, and 99 are calcium-carbonate in type; Nos. 32 and 35 are sodium-carbonate: and No. 36 is a calcium-sulphate water.

Chemical composition and classification of ground waters in Suffield.[a]

[Parts per million. Collected Dec. 6, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. IV.]

	Analyses.[b]		Assays.[c]			
	32	36	35	93	97	99
Silica (SiO_2)	21	32				
Iron (Fe)	.14	.19	0.17	0.08	0.2	0.07
Calcium (Ca)	15	65				
Magnesium (Mg)	6.6	17				
Sodium and potassium (Na+K)[d]	42	26	12	36	25	41
Carbonate radicle (CO_3)	.0	9.1	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	90	102	27	196	196	404
Sulphate radicle (SO_4)	17	176	3.0	23	23	45
Chloride radicle (Cl)	45	5.0	5.2	46	19	55
Nitrate radicle (NO_3)	.05	.10				
Total dissolved solids at 180° C	191	391	[d] 61	[d] 300	[d] 260	[d] 530
Total hardness as $CaCO_3$	[d] 65	[d] 232	9.1	178	162	375
Scale-forming constituents[d]	76	250	35	200	190	400
Foaming constituents[d]	119	70	30	100	70	110
Chemical character	Na-CO_3	Ca-SO_4	Na-CO_3	Ca-CO_3	Ca-CO_3	Ca-CO_3
Probability of corrosion[e]	N	(?)	N	(?)	(?)	(?)
Quality for boiler use	Good.	Poor.	Good.	Fair.	Fair.	Poor.
Quality for domestic use	Good.	Fair.	Good.	Good.	Good.	Bad.

[a] For location and other descriptive information see pp. 146–148.
[b] For methods used in analyses and accuracy of results see pp. 52–60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52–60.
[d] Computed.
[e] Based on computed quantity; N=noncorrosive, (?)=corrosion uncertain.

PUBLIC WATER SUPPLIES.

The residents of Suffield village and its environs are served by the Northern Connecticut Light & Power Co., and a few on the west bank of Connecticut River opposite Thompsonville are served by the Thompsonville Water Co. See p. 136.)

The Northern Connecticut Light & Power Co., which began the distribution of water in 1895 under another name, has two drilled wells (Nos. 108 and 108A, Pl. IV) in the northeast part of the town from which water is drawn by electrically driven pumps with their working cylinders about 220 feet below the surface. Water is delivered to a steel standpipe that has a capacity of 300,000 gallons on a hill a mile north of the village, from which it is distributed under a pressure of 45 to 50 pounds to the square inch through 13 miles of main to 34 fire hydrants and 301 service taps. There are 326 customers in Suffield and 12 in Agawam, Mass.,[1] and the average daily consumption by the 2,560 people served is about 52,000 gallons. The maximum consumption comes during the tobacco-planting season and is estimated by Mr. W. P. Schwabe, the superintendent, at about 140,000 gallons a day.

[1] Connecticut Public Utilities Commission Rept., 1917.

RECORDS OF WELLS AND SPRINGS.

Two springs were visited in Suffield (Nos. 49 and 79, Pl. IV). Spring No. 49 is piped by gravity about 200 feet to the house and is said never to fail. Spring No. 79 was improved by setting a barrel in it. The lower head was left in the barrel but was perforated by a number of ½-inch holes.

Wells dug in till in Suffield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
7		Slope	285	12.6	8.2	4.4	Chain pump	Nonfailing.
9		Ridge	270	26.5	23.9	2.6	do	Fails. Rock, 16 feet.
10		Plain	245	17.4	11.1	6.3	do	Nonfailing.
18		Ridge	245	20	16	4	Deep-well pump	Fails.
20		Slope	225	18.2	9.2	9.0	Chain pump	
24		Ridge	220	21.8	10.4	11.4	do	
28		Hill	225	26.0	10.6	15.4	do	Nonfailing.
29		do	215	21.4	14.4	7.0	do	
37	W. H. Peckham	do	165	23.6	10.6	13.0	Windlass rig	Fails.
38		Slope	195	12.4	9.0	3.4	Chain pump	Nonfailing.
39		Plain	190	22.2	11.6	10.6	do	
40		Slope	160	27.5	14.7	12.8	Windlass rig	Fails.
41		Hill	185	21.0	8.4	12.6	Chain pump	Do.
44		Plain	165	9.2	6.0	3.2	do	Nonfailing.
45		Terrace	185	21.4	7.5	13.9	do	Do.
46		Plain	185	22.8	16.3	6.5	do	Do.
55		do	215	9.6	4.4	5.2	Windlass rig and house pump.	Do.
70		Slope	165	21.0	14.7	6.3	Windlass rig	Do.
71		Hill	170	26.7	13.4	13.3	Chain pump	Do.
72		do	165	16.5	13.2	3.3	Windlass rig	
75		do	180	24.1	13.3	10.8	do	
76		do	180	22.3	10.1	12.2	do	Do.
86		Slope	195	26.8	13.9	12.9	Windlass and pulley rig.	Fails.
87		Hill	180	46.8	30.9	15.9	Windlass rig	Nonfailing.
88		Slope	140	27.3	15.1	12.2	Windlass and pulley rig.	Do.
89		do	130	15.5	8.8	6.7	House pump	Do.
91		Plain	130	29.6	16.6	13.0	Two-bucket rig	Nonfailing. Rock bottom.
92		Slope	110	18.7	15.0	3.7	Windlass rig	Nonfailing.
93	E. M. Austin	Hill	160	39.7	18.8	20.9	do	Nonfailing. Rock bottom. For assay see p. 145.
95		Slope	175	24.5	14.1	10.4	do	
99	Fred Brown	Knoll	125	20.4	6.8	13.6	Chain pump	Nonfailing. For assay see p. 145.
103		Slope	110	36.2	29.1	7.1	Two-bucket rig	
104		Plain	90	7.2	4.5	2.7	Chain pump	Nonfailing.
105		Slope	80	25.6	9.9	15.7	do	Fails.
106		Ridge	105	16.4	9.4	7.0	do	Do.

Wells dug in stratified drift in Suffield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Slope.......	215	11.2	7.4	3.8	Air-pressure system.	Nonfailing.
2	....	.....do......	250	20.5	14.9	5.6	Windlass rig.......	Fails.
4	....	Plain.......	250	8.3	5.7	2.6	Chain pump......	Nonfailing.
5	....	.....do......	250	10.2	8.0	2.2	.....do............	Fails.
6	....	.....do......	285	20.6	16.6	4.0	.....do............	Nonfailing.
8	....	.....do......	245	16.5	9.5	7.0	.....do............	Do.
11	....	.....do......	210	9.8	7.2	2.6	Windlass rig.......	Do.
12	....	.....do......	220	19.0	17.1	1.9	Chain pump......	Fails. Rock 3 feet.
14	....	.....do......	215	12.3	5.2	7.1	Sweep rig..........	Fails.
16	....	.....do......	220	12.9	9.1	3.8	Chain pump.......	
21	....	.....do......	195	19.6	15.4	4.2	Windlass rig.......	Nonfailing.
32	H. W. Kehoe.	.....do......	150	13.5	6.7	6.8	Chain pump and house pump.	Nonfailing. For analysis see p. 145.
33	....	.....do......	170	34.0	27.0	7.0	Deep-well pump..	Nonfailing.
35	C. B. Jobes..	.....do......	130	16.7	8.3	8.4	Chain pump......	Nonfailing. For assay see p. 145.
43	....	.....do......	140	13.7	8.0	5.7	Windlass rig.......	Nonfailing.
47	....	.....do......	245	10.9	7.7	3.2	.....do............	Do.
50	....	Slope.......	185	19.9	14.5	5.4	.....do............	Do.
51	....	.....do......	175	18.1	13.5	4.6	Windlass rig.......	Fails.
52	....	Plain.......	190	16.5	11.2	5.3	Chain pump......	Do.
53	....	.....do......	175	20.4	16.8	3.6	.....do............	Nonfailing.
54	....	Ridge.......	175	19.1	14.4	4.7	Windlass rig.......	Abandoned.
56	....	.....do......	185	10.5	6.5	4.0	Chain pump......	Nonfailing.
57	....	.....do......	185	20.6	15.5	5.1	.....do............	Fails.
62	....	Ridge.......	155	23.0	13.4	9.6	Two-bucket rig....	Do.
63	....	Plain.......	185	26.8	10.2	16.6	Chain pump......	Nonfailing.
65	....	.....do......	180	12.9	7.1	5.8	.....do............	Do.
66	T. H. Smith.	Slope.......	175	15.3	7.9	7.4	.....do............	Fails.
68	....	Plain.......	145	21 1	19.7	1.7	Windlass rig.......	
69	....	Slope.......	135	15.1	11.0	4.1	.....do............	Do.
73	....	Plain.......	125	14.7	8.4	6.3	.....do............	Do.
74	....	.....do......	125	15.4	10.8	4.6	Chain pump......	Do.
77	....	.....do......	175	19.9	5.9	14.0	.....do............	Nonfailing.
78	....	Slope.......	110	24.7	13.6	11.1	Windlass rig.......	Fails.
80	....	Plain.......	115	15.1	6.8	8.3	Chain pump......	Do.
81	....	.....do......	125	21.5	12.6	8.9	Windlass rig.......	Do.
82	....	Slope.......	135	19.4	10.7	8.7	Chain pump......	Nonfailing.
83	....	.....do......	145	20.0	16.0	4.0	.....do............	Do.
85	....	Plain.......	110	19.4	11.9	7.5	.....do............	Do.
90	....	Terrace....	125	28.7	25.7	3.0	Windlass rig.......	Fails.
96	....	Plain.......	130	20.9	13.2	7.7	Chain pump......	Do.
97	A. A. Brown.	Slope.......	120	25.6	18.1	7.5	.....do............	Nonfailing. Rock 10 feet. Water from sandstone. For assay see p. 145.
98	....	.....do......	115	23.7	17.6	6.1	....	Nonfailing.
100	....	Plain.......	120	15.9	11.2	4.7	Chain pump......	Do.
107	....	.....do......	85	10.4	6.0	4.4	.....do............	

Driven wells in Suffield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Depth.	Remarks.
			Feet.	*Feet.*	
15	....	Plain	215	30	Windmill rig.
22	....	.....do......	190	20	8 feet to water level.

Drilled wells in Suffield.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water.	Diameter.	Yield per minute.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Galls.*	
3	School	Plain	250	245	......	18	6	......	
13	Chas. H. King	Ridge	225	91	8	.....	6	$7\frac{1}{2}$	
17	John Nobel	...do	190	105	5	20	6	25	
19	......	...do	245	63	33	20	6	16	
23	A. L. Jackson	...do	230	183	53	30	6	40	
25	A. H. Wood	Slope	210	143	36	16	6	43	
26	George Hastings	...do	190	212	......	12	6	45	
27	Samuel Barr	...do	205	102	50	3	6	50	
30	L. A. King	...do	195	204	100	18	6	30	
31	Samuel Graham	...do	205	178	70±	13	6	75	
34	—— Tomlinson	Plain	160	203	60	45	6	15	
36	W. H. Peckham	Hill	160	$207\frac{1}{2}$	88	......	6	20	Water from sandstone. For analysis see p. 145.
42	Wm. Dakin	Slope	150	$114\frac{5}{2}$	1	25	......	11	
48	Holcomb Bros	...do	270	90±	9±	40	6	.6	
58	N. L. Miller	Plain	180	288	......	19	6	35	
59	P. D. Lilly	...do	185	123	40	18	6	23	
60	Wever	...do	180	154	30±	......	8	100	Water flows from casing.
61	.....do	...do	180	1 0	20	8	6	40	
64	John Wolchak	Slope	145	86	56	......	6	......	
67	......	Plain	145	250	......	......	6	......	
84	Geo. A. Peckham	Slope	145	165	90	13	6	20	
94	Hugh Bickerstaff	...do	160	131	32	24	6	24	
101	John Yunitis	...do	145	115	25	10	6	23	
102	.....do	Terrace	110	150	35	26	6	53	
108	Northern Connecticut Light & Power Co.	Hill	185	236	60	90	6	67	(*a*)
108A	.....do	...do	185	236	60	90	8	135	

a Further description under heading of "Public water supplies."

WINDSOR LOCKS.

AREA, POPULATION, AND INDUSTRIES.

Windsor Locks is a small manufacturing and agricultural town on the west bank of Connecticut River about 7 miles south of the Massachusetts boundary and 10 miles north of the city of Hartford. The area is about 8 square miles, of which about 5 square miles is wooded. The woodlands, which are in the main restricted to the western part of the town, are dominated by scrub oaks and yellow pines and have a typical underbrush of sweet fern and a yellowish grass, known locally as "poverty grass." There are about 30 miles of roads and streets in the town, including 3 miles of the State trunk-line highway between Hartford and Springfield. The roads in the west part of the town are very poor, as the soil is a loose sand.

Windsor Locks, the only settlement, is on the Hartford division of the New York, New Haven & Hartford Railroad and also on the West Side trolley line of the Hartford & Springfield Street Railway Co. There are hotels, a post office, and numerous stores and factories. Windsor Locks owes its prosperity to the power developed from the Enfield Canal, which ends in the southern part of the vil-

lage. Construction of the canal was begun in 1827, and the canal was opened to navigation in 1829.[1] The canal is about 5¼ miles long and the lifts aggregate about 30 feet. It is estimated that in 1880 between 1,800 and 1,900 horsepower was developed, but that there is available at least 15,000 horsepower.[2]

Windsor Locks was taken from Windsor in 1854 and incorporated as a separate town. Previous to this it had been a prosperous manufacturing place, the first factory having been built about 1830. In 1910 the population was 3,715, an increase of 653 over the population in 1900. The population is mostly concentrated in the village, and the west part of the town is very sparsely settled. At each census since its incorporation the town has shown a substantial increase in population, and it is to be expected that this growth will continue. The following table shows the gains in population together with the per cent of change for each census period:

Population of Windsor Locks, 1870–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1870	2,154		1900	3,062	+11
1880	2,332	+8	1910	3,715	+21
1890	2,758	+18			

[a] Connecticut Register and Manual, 1919, p. 641.

The principal industries of Windsor Locks are manufacturing of paper, cotton warp, machinery, underwear, and tinsel novelties, and agriculture, in which tobacco is the chief crop.

SURFACE FEATURES.

The surface of Windsor Locks is for the most part a sand plain ranging in elevation from 120 to 160 feet above sea level. Near the west end of the north boundary a low till-covered hill rises above the sand plain to an elevation of 180 feet above sea level. A strip a mile wide along the east boundary slopes gradually to Connecticut River but is trenched by several rather deep valleys tributary to the Connecticut. There are similar valleys tributary to Farmington River along the southwest boundary of the town.

During preglacial time Connecticut River had a broad valley, which included the territory of Windsor Locks and in which were a number of hills. During the invasion of the ice the valley was deepened somewhat and a mantle of till was laid over much of the bed-

[1] Stiles, H. R., History and genealogies of ancient Windsor, p. 507, 1892.

[2] Porter, Dwight, Tenth Census report on water power of the United States, pt. 1, pp. 217–219, 1885.

rock. As the ice was receding the numerous streams derived from the melting ice filled the valley with a thick mantle of stratified drift, which now forms the sand plain. Some of the hills were high enough to escape burial by the stratified drift, and the low hill in the northwestern part of the town is of this type. Records of drilled wells in East Windsor and in Windsor, tabulated by Ellis,[1] show that the thickness of the stratified drift is 70 to 168 feet in some places.

During postglacial time Connecticut River and Farmington River have cut valleys about a mile wide and 80 to 120 feet deep in the stratified drift. Narrower and shallower valleys have been cut by their tributaries.

Short tributaries of Connecticut and Farmington rivers drain Windsor Locks. In the northern and western parts of the town there are extensive areas with no streams of sufficient size to be shown on the maps (Pls. IV and V). Evidently the water derived from the rain and snow that fall on these areas, except the part that evaporates, is entirely absorbed and becomes part of the ground-water body. Along the stream valleys cut in the stratified drift are numerous large springs, such as those that feed the reservoir of the Windsor Locks Water Co. The high porosity and dryness of the surface soil is further shown by the xerophytic character of the flora.

WATER-BEARING FORMATIONS.

Till.—The only till area in Windsor Locks is one of a few acres on a low hill on the Suffield boundary, but no wells were found there. The occurrence of water in the till is the same as in the till of the adjacent towns. (See p. 143.)

Stratified drift.—Stratified drift comprises all the débris washed out from the ice sheet as it melted back, together with eroded portions of the till and of the bedrock. There are beds and lenses of clay, silt, sand, and gravel, which lie on one another and interfinger in a very intricate way. Within each bed or lens the grains are of very uniform size and most of them are well rounded. As a consequence the total pore space is great, and beds are high in permeability. Rain is readily absorbed, and the water sinks downward until it reaches a zone of saturation. Wells dug or driven deep enough to penetrate the saturated zone are likely to obtain abundant and dependable supplies of water. Fourteen such wells were visited in Windsor Locks in July and August, 1916. Ten were said to be non-

[1] Gregory, H. E., and Ellis, A. J., Ground water in the Hartford, Stamford, Salisbury, Willimantic, and Saybrook areas, Conn.: U. S. Geol. Survey Water-Supply Paper 374, pp. 86, 90, 1916.

failing and three were said to fail. The reliability of the other one was not ascertained. The data collected concerning the depths of these wells are summarized in the following table:

Summary of wells in Windsor Locks.

	Total depth.	Depth to water.	Depth of water in wells.
	Feet.	*Feet.*	*Feet.*
Maximum	11.8	39.3	8.8
Minimum	6.6	3.8	2.5
Average	19.6	15.2	4.3

QUALITY OF GROUND WATER.

The accompanying table gives the results of one analysis and one assay of samples of ground water collected in Windsor Locks. No. 6 is low in total mineral content; No. 13 is moderately mineralized. Both are soft. So far as their mineral character is concerned, the waters are acceptable for domestic use, although the high nitrate in No. 6 may indicate pollution. No. 6 is considered good for boiler use, but on account of the large amount of scale-forming ingredients in No. 13 it is considered only fair for boiler use. No. 6 is calcium-carbonate in type, and No. 13 is a calcium-chloride water.

Chemical composition and classification of ground waters in Windsor Locks.[a]

[Parts per million. Collected Dec. 6, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analysis and assay correspond to those used on Pl. IV.]

	Analysis.[b]	Assay.[c]
	6	13
Silica (SiO_2)	18	....
Iron (Fe)	.31	0.12
Calcium (Ca)	12	....
Magnesium (Mg)	5.0	....
Sodium and potassium (Na+K)[d]	12	21
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	39	38
Sulphate radicle (SO_4)	17	43
Chloride radicle (Cl)	5.8	34
Nitrate radicle (NO_3)	23	....
Total dissolved solids at 180° C	104	[d] 180
Total hardness as $CaCO_3$	[d] 50	83
Scale-forming constituents [d]	62	110
Foaming constituents [d]	32	60
Chemical character	Ca-CO_3	Ca-Cl
Probability of corrosion [e]	(?)	(?)
Quality for boiler use	Good.	Fair.
Quality for domestic use	Good.	Good.

[a] For location and other descriptive information see p. 152.
[b] For methods used in analysis and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assay and reliability of results, see pp. 52-60.
[d] Computed.
[e] Based on computed quantity; (?)=corrosion uncertain.

PUBLIC WATER SUPPLY.

The village of Windsor Locks has been supplied with water by the Windsor Locks Water Co. since 1892. Water from a spring-fed brook in the southeast part of the town is intercepted in two reservoirs of 90,000 and 240,000 gallons capacity, from which it is pumped by electricity to a standpipe on a hill northwest of the village. The water is distributed by gravity under a pressure of 70 pounds to the square inch through 10½ miles of main pipe to 68 fire hydrants and 592 service taps. Between 2,500 and 3,000 people are served and consume about 227,000 gallons a day on the average. The main pump has a capacity of 1,000 gallons a minute, and there are in addition a 750-gallon pump driven by a heavy oil engine and a 350-gallon pump driven by a kerosene engine. The present supply is adequate to meet the demands on the system, and the company owns another brook from which twice as much water can be drawn as from the one utilized at present.

Wells in Windsor Locks.

No. on Pl. IV.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Plain......	165	11.5	5.8	5.7	Pitcher pump...	Nonfailing, tiled.
3	....	.....do.....	165	20	....	....	.....do..........	Nonfailing. Driven well.
4	....	.....do.....	145	25.2	22.4	2.8	Chain pump....	Nonfailing.
5	....	.....do.....	145	37	30	7	Deep-well pump	Do.
6	Frank Deball...	.....do.....	145	41.8	39.3	2.5	Windlass rig....	Water from stratified drift. For analysis see p. 151.
7	....	.....do.....	140	19.9	16.0	3.9	Two-bucket rig .	Nonfailing.
8	....	Terrace....	140	14.2	5.4	8.8	Chain pump....	Fails.
9	Mrs. L. A. Webb.	Plain......	95	16.1	13.3	2.8	House pump....	Nonfailing.
10	....	.....do.....	80	6.6	3.8	2.8	No rig..........	Do.
11	....	.....do.....	65	9.5	5.8	3.7	.....do..........	Do.
12	....	.....do.....	50	11.2	8.4	2.8	Chain pump....	Do.
13	P. Fournier.....	Terrace....	30	22.9	19.2	3.7	House pump and windlass rig.	Fails. Fluctuates with the river. Water from stratified drift. For assay see p. 151.
14	....	.....do.....	20	22.1	18.8	3.3	House pump....	Fails.
15	....	Slope......	25	16.2	10.0	6.2	Windlass rig....	Nonfailing.

GLASTONBURY.

AREA, POPULATION, AND INDUSTRIES.

Glastonbury is an extensive town near the southeast corner of Hartford County and lies on the east shore of Connecticut River. It is about 5 miles southeast of the city of Hartford and 8 miles north of Middletown. The town has an area of 54 square miles, of which 30½ square miles or 55 per cent is wooded. There are very few woods in the western part of the town; the middle is largely wooded; and the very hilly eastern part is almost entirely covered with woods.

The town works about 125 miles of dirt roads. There are in addition 4 miles of the Hartford-New London State trunk highway and 6 miles of road maintained in part by the State. These roads are surfaced with bituminous macadam. The principal settlements are Glastonbury and South Glastonbury, near the northwest and southwest corners, respectively. Hopewell is a small settlement on Roaring Brook, 2 miles east of South Glastonbury. East Glastonbury is on the same stream 3 miles farther northeast. Addison and Buckingham are 1½ and 5 miles east of Glastonbury, respectively. Naubuc, another small village, is 1½ miles northwest of Glastonbury. Post offices are maintained at Glastonbury, South Glastonbury, East Glastonbury, and Addison, and the outlying districts are served by rural delivery. A ferry at South Glastonbury connects with the Valley division of the New York, New Haven & Hartford Railroad at Rocky Hill. A trolley line from Hartford runs to Glastonbury and South Glastonbury. During the open season there is steamboat connection to Hartford and New York.

Glastonbury was taken from Wethersfield in 1690 and incorporated as a separate town. In 1803 about 4 square miles was taken to make part of Marlboro, and in 1813 1½ square miles more was ceded. In 1910 the population of Glastonbury was 4,796, which is equivalent to a density of 89 to the square mile. Much of the population is concentrated in the several villages, so that most of Glastonbury is sparsely settled. The following table shows the changes in population since 1756:

Population of Glastonbury, 1756–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1756	1,115		1840	3,077	+ 3
1774	2,071	+86	1850	3,390	+10
1782	2,346	+13	1860	3,363	− 1
1790	2,732	+16	1870	3,550	+ 6
1800	2,718	− 1	1880	3,580	0
1810	2,766	+ 2	1890	3,457	− 3
1820	3,114	+13	1900	4,260	+23
1830	2,980	− 4	1910	4,796	+12

[a] Connecticut Register and Manual, 1919, p. 638.

There have been no great nor persistent tendencies toward decrease in population at any time, and the gains have exceeded the losses. A continuation of the moderate, uniform growth is to be expected. The principal industries are agriculture, tobacco and orchard fruits being the chief crops, and the manufacture of soap and other toilet preparations, paper, woolen and knit goods, and silverware.

SURFACE FEATURES.

Glastonbury is in part in the central lowlands of Connecticut and in part in the eastern highland. The lowland includes a strip a

mile wide along the south part of the Connecticut River boundary and also the area northwest of a line from South Glastonbury past the foot of Eightmile Hill and Minnechaug Mountain. It is underlain by relatively soft sedimentary rocks that have been eroded more completely than the more resistant schists and gneisses of the highland. The highest point in the lowland is 420 feet above sea level, whereas the peaks of Birch Mountain are about 920 feet above sea level. The difference of general level between the lowland and highland was produced by preglacial erosion, as were also their major topographic features, but the minor details are in large part due to glacial and postglacial processes. Along Connecticut River and in the valleys of Salmon and Roaring brooks there are areas underlain by stratified drift deposited by streams that issued from the glacier during its recession. Parts of these areas retain their original flatness, but the higher parts have been extensively eroded.

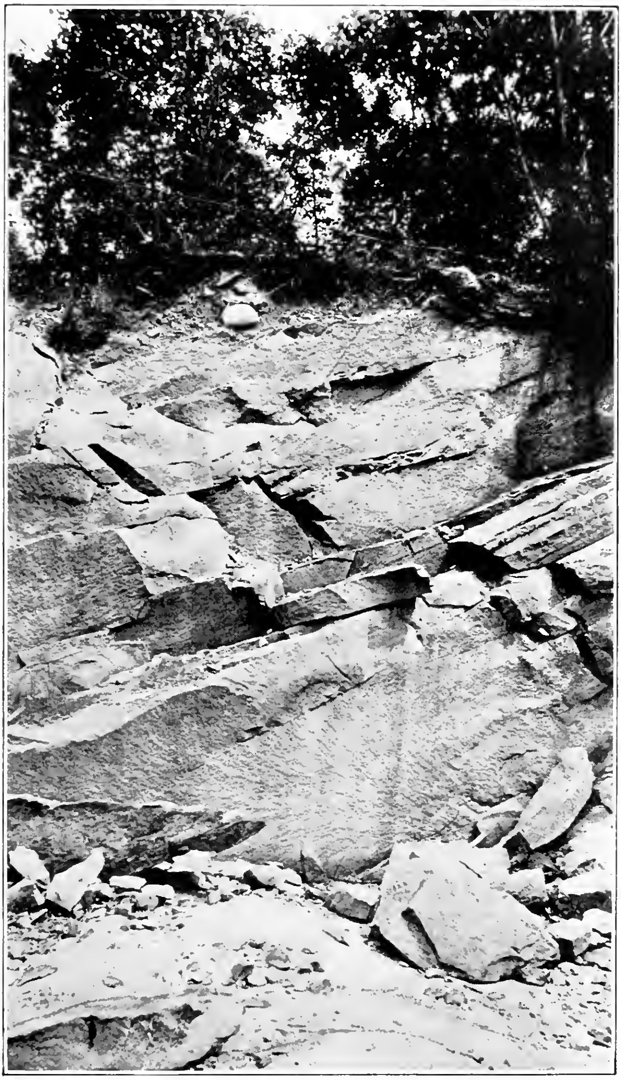
Most of Glastonbury is drained by streams tributary to Connecticut River, the largest of which are Salmon Brook, which has its mouth at Naubuc, and Roaring Brook, which empties at South Glastonbury. About 6 square miles in a strip along the Marlboro and Hebron town lines is drained by headwaters of Blockledge River and Dickinson Creek, which flow through Marlboro and join Salmon River, which is tributary to the Connecticut at East Haddam.

WATER-BEARING FORMATIONS.

Five types of bedrock have been recognized in Glastonbury—Triassic red sandstone, Glastonbury granite gneiss, Hebron gneiss, Maromas granite gneiss, and Bolton schist.[1]

Schist and gneiss.—The Bolton schist is for the most part a typical silvery-gray mica schist composed essentially of quartz, feldspar, and mica (chiefly white), with minor amounts of accessory minerals, such as biotite (black mica), garnet, staurolite, and in places magnetite, graphite, pyroxene, and chlorite. Originally this formation was a series of clays, silts, and sands that were consolidated into shales and sandstones, which in turn have been subjected to great pressure and heating and have been metamorphosed. In places in Glastonbury the rock is very dark gray, as it contains a good deal of graphite derived from organic materials in the original sediments. The Bolton schist underlies a northward-striking belt a quarter of a mile wide that runs through the eastern part of the village of South Glastonbury, and a belt half a mile wide near the east boundary, including Birch Mountain, from which it extends south-southwest. This formation is very resistant and everywhere makes ridges that stand up above the neighboring formations.

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.



MASSIVE GRANITE GNEISS, EAST GLASTONBURY, CONN.

The Glastonbury granite gneiss underlies an area of about 26 square miles, including Minnechaug Mountain, Kongskut Mountain, Eightmile Hill, and Meshomasic Mountain. It is quarried for building stone at a number of places. According to Gregory,[1] it may

be divided into two parts—a broad western portion, decidedly gneissoid and usually dark colored, with a large quantity of biotite and hornblende; a narrower eastern portion, more granitic, and in places reaching the massiveness of a true granite. * * * As seen in the abundant exposures west of the Portland Reservoir, it is a dark, well-foliated, almost schistose gneiss of fine grain, which on the cleavage surface shows alternating patches of black biotite and white feldspar. * * * The presence of biotite and hornblende, arranged in parallelism with aggregates of feldspar, gives a distinct foliation and banding to the rock. * * * This more schistose variety forms the hills southeast of Glastonbury and occurs in the bed of Roaring Brook in South Glastonbury. * * * The more massive variety of this gneiss is seen in the small quarries north of East Glastonbury. The rock here is a light-colored fine-grained biotite gneiss or granite, which sometimes is quarried in blocks 2 or 3 feet in thickness, with no sign of a parting. * * * In regard to the origin of the Glastonbury gneiss there is strong indication that it is in large part igneous; and this applies both to the more massive eastern portion and the more gneissic variety on the west.

Plate XII is a view in one of the small quarries in the massive phase of the Glastonbury granite gneiss and shows the massive character and the jointing of the rock.

The Maromas granite gneiss underlies a strip a quarter of a mile wide west of the Bolton schist area of South Glastonbury and also a strip half a mile to a mile wide east of the eastern Bolton schist area and along the Marlboro and Hebron town lines. It is for the most part a typical granite gneiss, composed essentially of quartz, feldspar, and mica with subordinate amounts of other minerals. Much of it has been crushed and mashed, which has given it a gneissic texture. Other phases are more basic and darker colored because of the presence of hornblende.

The Hebron gneiss underlies a very small area in Glastonbury along the boundary where it touches the towns of Marlboro and Hebron. According to Gregory,[2] it "varies from a granitic gneiss to a highly fissile schist," and "where typically developed is a fine-grained gneiss, with a relatively small amount of feldspar."

As regards their water-bearing capacity these granite gneisses and the schist are essentially alike, but no supplies from them have been obtained in Glastonbury. The dynamic stresses that metamorphosed them also made many fractures, which form systems of parallel, flat openings. In general there is a set roughly horizontal and one or

[1] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, pp. 116–119, 1906.

[2] Idem, p. 141.

more about at right angles to it. Rain water which has soaked into the overlying unconsolidated soil in part finds its way into the interconnecting fissures. Elsewhere in the State wells drilled into similar rocks obtain dependable and reasonably abundant supplies of water from the fissures. Drilling into the schist or gneiss at any point in Glastonbury would probably yield equally satisfactory results. Small amounts of water are contained in the minute lamellar openings between the mica flakes of the schist and the schistose phases of the gneisses, but they are negligible.

Red sandstone.—The lowland portion of Glastonbury is underlain by red sandstone with which are associated some red shale and conglomerate. During the Triassic period a great valley, bounded on the east by a great fault, existed in central Connecticut. Into this valley were washed sands, clays, and gravels that were consolidated to form sandstones, shales, and conglomerates. The beds were originally flat-lying but continued faulting along the eastern border tilted them to the east. At the same time jarring and crushing opened many joints and made new fractures in the rocks. Water is carried in them in the same way as in the fissures in the gneiss and schist. Two drilled wells which presumably obtain their water in this way were visited in Glastonbury. There may be porous zones in the sandstone and conglomerate which carry considerable amounts of water, but none have been recognized.

Till.—The bedrock of the higher parts of Glastonbury, except the areas of actual rock outcrop, is mantled with till, the product of direct glacial deposition. It forms a layer ranging in thickness from a few feet to 50 feet, and comprises all the débris plucked and ground beneath the ice sheet. In a matrix of fine rock flour, clay, silt, and sand larger fragments are embedded. Because of the intimate mixture of particles of irregular shapes and the packing of the smaller into the interstices between the larger by the great weight of the ice, the till forms a dense tough mass and has moderate porosity and permeability. Water which has fallen as rain is in part absorbed by the till and slowly transmitted by gravity. Below a certain depth, which differs from place to place and from time to time, the minute pores of the till are saturated with water, which may be recovered by means of dug wells. In general it is advisable to dig the well to bedrock, as the zone immediately above the bedrock is the most thoroughly saturated and therefore yields the best supplies. In some places this is impossible, but wells which extend below the lowest level reached by the top of the saturated zone during droughts are reasonably certain to procure constant supplies of water sufficient for ordinary domestic and farm needs. In August, 1916, measurements were made of 42 wells dug in till in Glastonbury. Of these wells 11 were said never to fail and 15 were said to fail, but the re-

liability of the other 16 was not ascertained. The data concerning the depths of the 42 wells are summarized in the following table:

Summary of wells dug in till in Glastonbury.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	42.4	32.9	7.5
Minimum	10.1	5.3	1.8
Average	21.0	16.9	4.1

Stratified drift.—The mantle rock of the lower parts of Glastonbury is stratified drift. The boundary between it and the till is in general about 200 feet above sea level but is higher in the valleys to the east. East of East Glastonbury there is a knoll of stratified drift which has an elevation of 520 feet. Stratified drift is not the product of direct glacial deposition, as is the till, but was laid down by water derived in large part from the melting of the ice. Many streams issued from the receding glacier and bore much débris, which they dropped near the ice front, forming broad glacial-outwash plains in the broad valleys and narrower plains and terraces in the smaller valleys. The stratified drift consists for the most part of the constituents of the till and débris carried from the glacier. These materials have been sorted according to size, thoroughly washed, and finally laid down in separate beds and lenses. Inasmuch as the finer particles have been removed from the interstices between the larger ones, and the grains themselves worn from subangular to well-rounded shapes, the stratified drift is both higher in total porosity and of greater perviousness than the till. It absorbs water more quickly and in larger amounts and transmits it more readily. Wells dug in stratified drift procure water in the same way as wells in till but on a more generous scale. The supplies are in general more reliable, unless the well in stratified drift is so situated that the ground water may drain from it readily. Measurements were made of 42 wells dug in stratified drift in Glastonbury. Of these wells 30 were said never to fail and 6 to fail; the reliability of the other 6 was not ascertained. The following table summarizes the data collected concerning the depths of these 42 wells:

Summary of wells dug in stratified drift in Glastonbury.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	32.9	23.7	15.9
Minimum	5.6	1.0	1.2
Average	17.4	10.5	6.9

It is said by the residents that on the knoll of stratified drift east of East Glastonbury it would be necessary to dig wells to a depth of 80 feet in order to reach the water level. This may be an excessive estimate, but it is entirely reasonable to suppose that the water lies at an unusually great depth at this point, as the topographic situation is very disadvantageous for the retention of ground water. At present the people living on this knoll depend largely upon rain water collected from roofs and stored in cisterns.

QUALITY OF GROUND WATER.

The following table gives the results of two analyses and four assays of samples of ground water collected in the town of Glastonbury. The waters are all low in mineralization except Nos. 15 and 2, which are moderately mineralized. No. 15 is a soft water, No. 2 is comparatively hard, and the rest are very soft. All are suitable for domestic use, so far as this may be determined by their mineral content. All are good for boiler use except No. 2, which is rated as fair because the scale-forming ingredients are a little high. All are sodium-carbonate waters except No. 2, which is calcium-carbonate in type.

Chemical composition and classification of ground waters in Glastonbury.[a]

[Parts per million. Collected Dec. 2, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. VI.]

	Analyses.[b]		Assays.[c]			
	15	21	2	57	59	68
Silica (SiO_2)	22	18				
Iron (Fe)	.28	.20	0.81	Trace.	0.18	0.37
Calcium (Ca)	19	8.7				
Magnesium (Mg)	3.8	2.3				
Sodium and potassium (Na+K)[d]	28	11	Trace.	11	19	13
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	71	37	54	22	43	31
Sulphate radicle (SO_4)	33	13	38	2.0	3.0	9.0
Chloride radicle (Cl)	22	5.8	17	5.1	20	5.6
Nitrate radicle (NO_3)	1.1	2.9				
Total dissolved solids at 180° C	174	78	[d] 160	[d] 55	[d] 99	[d] 74
Total hardness as $CaCO_3$	[d] 63	[d] 31	128	6.0	28	16
Scale-forming constituents[d]	84	48	150	30	55	40
Foaming constituents[d]	76	30	(e)	30	50	30
Chemical character	Na-CO_3	Na-CO_3	Ca-CO_3	Na-CO_3	Na-CO_3	Na-CO_3
Probability of corrosion[f]	(?)	(?)	(?)	N	N	N
Quality for boiler use	Good.	Good.	Fair.	Good.	Good.	Good.
Quality for domestic use	Good.	Good.	Good.	Good.	Good.	Good.

[a] For location and other descriptive information see pp. 159-161.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Computed.
[e] Less than 10 parts per million.
[f] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

PUBLIC WATER SUPPLIES.

The villages of Glastonbury and Naubuc are supplied with water by the waterworks of the fire district of East Hartford, which have been described by Ellis.[1] The two reservoirs of this system, from which water is distributed by gravity, are on brooks in the hills of the northern part of Glastonbury and have capacities of 1,700,000 and 1,500,000 gallons, respectively.

Since 1905 the residents of South Glastonbury have had water from the South Glastonbury Water Co. There are two reservoirs on Ashley Brook, the upper of which has a capacity of 4,000,000 gallons and the lower of 500,000 gallons. Water is distributed by gravity under a pressure of 60 to 100 pounds to the square inch through 4 miles of main pipe to 95 service connections.[2]

RECORDS OF WELLS AND SPRINGS.

The only spring visited in Glastonbury (No. 31, Pl. VI) is in a swale and is improved with a large tile. Its water was found to have a temperature of 59° F.

Wells dug in till in Glastonbury.

No. on Pl. VI.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
23	....	Slope.......	310	13.8	4.3	9.5	Windlass rig....	Fails.
26	....	.....do.....	375	9.0	5.3	3.7	No rig..........	Do.
30	Herbert E. Mitchel	.....do.....	380	18.3	11.6	6.7	Two-bucket rig..	Nonfailing.
36	....	Plateau..	530	11.0	6.6	4.4	Chain pump....	
37	....	Slope......	445	12.0	7.4	4.6	Windlass rig....	Do.
39	M. R. Tryon........	.....do.....	425	23.0	16.5	6.5	.....do..........	Fails.
43	....	.....do.....	480	13.3	8.2	5.1	.....do..........	Do.
44	....	.....do.....	550	14.5	8.1	6.4	Two-bucket rig .	Nonfailing.
47	....	.....do.....	460	17.3	11.3	6.0	Windlass rig....	Do.
49	....	Plain......	465	26.9	23.7	3.2	.....do..........	Fails; abandoned.
51	Jerome P. Weir, jr..	Slope......	520	19.5	10.3	9.2	Chain pump....	
52	....	.....do.....	550	19.8	13.4	6.4	.....do..........	Nonfailing.
53	....	.....do.....	650	6.1	1.0	5.1	Sweep rig.......	Do.
54	....	.....do.....	435	13.3	8.6	4.7	Windlass rig....	Fails.
55	Peter Zimmerman..	Plain......	385	14.9	10.0	4.9	No rig..........	
56	....	Slope......	455	30.3	27.0	3.3	Windlass and counterbalance rig.	Nonfailing.
62	....	.....do.....	410	19.0	13.3	5.7	Two-bucket rig..	Do.
63	....	.....do.....	425	14.7	5.4	9.3	No rig..........	
64	....	.....do.....	445	25.7	10.1	15.6	Windlass rig....	Do.
65	....	.....do.....	630	15.8	9.4	6.4	Sweep rig.......	
66	....	.....do.....	675	5.6	1.9	3.7	No rig..........	Do.
67	....	.....do.....	580	14.1	5.7	8.4	Windlass rig....	Fails.
68	John Kelly.........	.....do.....	210	15.0	13.8	1.2	.....do..........	Fails. Rock bottom. For assay see p. 158.
69	....	Plain......	260	17.4	10.0	7.4	.....do..........	
70	....	Slope......	350	16.3	11.6	4.7	House pump....	Nonfailing.
71	....	.....do.....	375	32.9	20.5	12.4	Windlass rig....	Do.

[1] Gregory, H. E., and Ellis, A. J., Ground water in the Hartford, Stamford, Salisbury, Willimantic, and Saybrook areas, Conn.: U. S. Geol. Survey Water-Supply Paper 374, p. 71, 1916.

[2] Connecticut Public Utilities Comm. Rept., 1917.

Wells dug in till in Glastonbury—Continued.

No. on Pl. VI.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
72		Slope	410	19.0	8.5	10.5	Two-bucket rig	Fails.
73		do	470	19.1	13.9	5.2	do	Nonfailing.
74		do	475	9.7	7.2	2.5	House pump	
75		do	400	11.5	6.7	4.8	Windlass rig	
76		do	420	24.3	15.3	9.0	do	Fails.
77		do	410	19.0	11.7	7.3	Two-bucket rig	Nonfailing.
78		do	490	19.8	8.4	11.4	Windlass rig	
79		do	470	18.9	14.3	4.6	Chain pump	
80		Hill	725	17.7	13.1	4.6	Windlass rig	
81	Eugene Loveland	Terrace	680	18.5	15.5	3.0	do	Do.
82		Plain	710	9.2	7.8	1.4	No rig	Fails.
83		Plateau	730	18.3	7.5	10.8	Windlass rig	Do.
84		Hilltop	885	15.4	10.9	4.5	do	Do.
85		do	885	11.0	6.2	4.8	Two-bucket rig	Do.
86	B. Zola	Slope	910	21.9	15.9	6.0	Windlass rig	Do.
87		do	890	26.4	13.8	12.6	do	

Wells dug in stratified drift in Glastonbury.

No. on Pl. VI.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1		Plain	25	20.5	16.6	3.9	Chain pump	Nonfailing.
2	Mr. Neuscheler	do	35	10.4	7.3	3.1	do	Nonfailing. For assay see p. 158.
3		do	25	12.0	7.7	4.3	do	Nonfailing.
4		do	30	13.3	10.4	2.9	Two-bucket rig	Do.
5		do	35	10.5	5.8	4.7	Chain pump	Do.
6		Slope	80	16.3	12.8	3.5	do	Do.
7		Plain	30	10.8	8.1	2.7	do	
8		do	35	12.0	6.5	5.5	Windlass rig	Fails.
9		Terrace	60	12.6	10.8	1.8	No rig	Nonfailing. Abandoned.
10		Plain	50	18.3	14.5	3.8	do	Do.
11		do	75	19.5	17.3	2.2	Windlass rig	Nonfailing.
12		do	45	13.7	10.8	2.9	Chain pump	Nonfailing. Abandoned.
13		Slope	55	14.5	8.0	6.5	No rig	Abandoned.
14		Plain	45	11.5	8.4	3.1	Chain pump	Nonfailing.
15	William Staslinger	Slope	85	40.3	34.7	5.6	Windlass rig	Nonfailing. For analysis see p. 158.
16		Terrace	60	23.9	18.6	5.3	do	Nonfailing.
17		Plain	15	23.4	19.7	3.7	Two-bucket rig	Do.
18		do	30	42.4	39.9	2.5	Windlass rig	Do.
19		do	20	34.6	31.7	2.9	do	Do.
20	Louis C. Tryon	Terrace	25	40.4	38.1	2.3	do	Do.
21	G. A. Blinn	Slope	175	18.9	12.2	6.7	do	Nonfailing. For analysis see p. 158.
22	Mrs. L. Bacon	do	195	34.7	29.3	5.4	do	Nonfailing.
24	David R. Taylor	Plain	170	32.8	30.3	2.5	Two-bucket rig	Fails.
25		do	170	16.0	10.8	5.2	Chain pump	Do.
27		do	180	16.5	12.2	4.3	Windlass rig	Nonfailing.
28		Terrace	250	16.2	11.3	4.9	Chain pump	Do.
32	George Kingston	do	305	40.0	38.2	1.8	Windlass rig	Do.
33		Slope	305	27.7	20.5	7.2	Pitcher pump, horse pump, and windlass rig.	Fails.
34		Plain	315	18.2	14.8	3.4	Deep-well pump	Nonfailing.
35		Terrace	340	19.3	16.2	3.1	Windlass rig	Do.
38		do	415	33.8	28.4	5.4	do	Do.
41		Plain	350	14.9	11.1	3.8	No rig	House destroyed.

Wells dug in stratified drift in Glastonbury—Continued.

No. on Pl. VI.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
42	....	Valley.....	400	12.5	5.3	7.2	Chain pump....	
45	....	.....do.....	410	19.5	16.4	3.1	Windlass rig....	
46	Albert L. Peck....	Plain......	435	17.5	10.0	7.5	Chain pump....	Nonfailing.
48	....	.....do.....	450	12.7	9.2	3.5	Windlass rig....	
50	....	Terrace....	450	38.6	35.9	2.7	Two-bucket rig..	Do.
57	John Vail.........	.....do.....	260	18.9	12.6	6.3	Windlass rig....	Nonfailing. For assay see p. 158.
58	....	.....do.....	250	15.6	13.7	1.9	Two-bucket rig..	Nonfailing.
59	J. W. Dailey......	.....do.....	400	23.0	17.5	5.5	Windlass rig....	Fails. For assay see p.158.
60	....	.....do.....	390	14.6	12.5	2.1	House pump....	Nonfailing.
61	....	.....do.....	380	18.7	14.4	4.3	Windlass rig....	Fails.

Drilled wells in Glastonbury.

No. on Pl. VI.	Owner.	Topographic situation.	Elevation above sea level.	Total depth.	Depth to rock.	Depth to water in well.	Diameter.	Yield per minute.	Kind of rock.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*	*In.*	*Galls.*		
29	Herbert E. Mitchell	Slope...	360	224	10	0	6	14	Sandstone.	Water flows from casing.
40	M. R. Tryon.......	...do....	430	64	12	10	6	12	...do..	

MARLBORO.

AREA, POPULATION, AND INDUSTRIES.

Marlboro is a small highland farming town in the southeast corner of Hartford County. It is 10 miles east of Middletown and 15 miles southeast of Hartford. The town has an area of 23 square miles, of which four-fifths is wooded. The town keeps in condition about 40 miles of roads, and there are in addition 7 miles of roads which have been discontinued. Eventually the State trunk line between Hartford and New London will run through the town. There are stations of the Air Line division of the New York, New Haven & Hartford Railroad at East Hampton and Lyman Viaduct. Marlboro, a rather straggling village, is the only settlement. In 1803 the town was organized, about 4 square miles of territory being taken from Glastonbury, 9 from Hebron, and 9 from Colchester. In 1813 1½ square miles more was annexed from Glastonbury.[1] In 1910 the population was 302, a decrease of 20 from the population in 1900. This is equivalent to a density of population of 13 inhabitants to the

[1] Hall, Mary, Marlboro, Conn., from 1736 to 1903, p. 34.

square mile. Marlboro has the smallest population of the towns in the State, and only one other town has a lower density of population. In general there has been a very decided decrease in population. In the first half of the nineteenth century there was some manufacture of cotton cloth for shipment to the South, but this ceased during the Civil War and was never revived. About 1885 a mill was built for the manufacture of silk, especially ribbon, and a number of workmen were brought in, but this enterprise was not long lived. The changes in population shown in the following table reflect the varying prosperity of the mills and the general tendency to move from farms to manufacturing centers:

Population of Marlboro, 1810–1910.[a]

Year.	Population.	Per cent change.	Year.	Population.	Per cent change.
1810	720		1870	476	−30
1820	839	+17	1880	391	−18
1830	704	−16	1890	582	+49
1840	713	+ 1	1900	322	−45
1850	832	+17	1910	302	− 6
1860	682	−18			

[a] Connecticut Register and Manual, 1919, p. 639.

At present the principal industry is mixed agriculture. There is also considerable charcoal burning and production of native lumber.

SURFACE FEATURES.

Marlboro lies in a thoroughly dissected plateau region. The hilltops range in elevation from 500 feet above sea level in the south part of the town to 700 feet in the north. They are remnants of a flat surface below which the streams have cut deep valleys, and most of them are in the form of ridges elongated in a north-south direction. Their direction is not dependent on the rock structure but is rather the result of the original direction of the streams. There are several points about 720 feet above sea level, the greatest elevation in Marlboro. The lowest point is where Blockledge River crosses the Colchester town line at an elevation of 200 feet above sea level.

Dickinson Creek, Blockledge River, and Fawn Brook and their tributaries drain Marlboro. They are all tributary to Salmon River, which enters Connecticut River at East Haddam.

WATER-BEARING FORMATIONS.

Three types of bedrock have been recognized by Gregory[1] in Marlboro—the Bolton schist, Maromas granite gneiss, and Hebron

[1] Gregory, H. E., and Robinson, H. H., Preliminary geological map of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 7, 1907.

gneiss. The unconsolidated mantle rocks include till and stratified drift. The former is the most important source of ground water in the town.

Schist and gneiss.—The Bolton schist underlies an area of a quarter of a square mile in the west corner of Marlboro where it borders on East Hampton and Glastonbury. It is a fairly typical mica schist composed of granules of quartz and feldspar in large part surrounded and enwrapped by flakes of mica. The mica flakes, by reason of their cleavability and roughly parallel arrangement, give the rock its fissile character, and they also give it a gray color with something of a silvery luster.

The Maromas granite gneiss underlies a northward-striking belt of country a mile wide adjoining the Bolton schist area and west of Marlboro Pond. This rock is of variable character, but typically it is a biotite gneiss composed essentially of quartz, feldspar, and biotite (black mica) with small amounts of accessory minerals. Its boundary against the Bolton schist is not sharp, for it sends stringers into the schist.

The Hebron gneiss, which underlies about 85 per cent of the area of the town, according to Gregory,[1] " varies from a granitic gneiss to highly fissile schist." On one side it grades into a true gneiss and on the other into schists.

These rocks are to all intents and purposes alike as far as their ability to carry water is concerned. The stresses which metamorphosed them also made many cracks and joints. Water which falls as rain is in part absorbed by the overlying unconsolidated till and stratified drift. Some of this water is slowly transmitted to the network of interconnecting joints, through which it circulates under gravity, and it may be recovered by means of drilled wells. A hole drilled into these rocks at any point will probably cut one or more of these water-bearing fissures and so procure a supply of water adequate in abundance and reliability for ordinary domestic and farm needs.

Till.—Till overlies the bedrock of Marlboro, except for the numerous small areas of actual rock outcrop and an area of stratified drift in a valley northwest of Marlboro Pond. (See map, Pl. VII.) It forms a mantle that is in general 10 to 40 feet thick and is composed of all the débris plucked and ground along beneath the ice. Pebbles, cobbles, and boulders of great and small size are embedded in a matrix of tightly packed sand, silt, clay, and fine rock flour. The constituent particles are in large part angular, so that they interlock and bind one another together. Much of the till is in consequence very dense and tough, as is indicated by the name " hardpan "

[1] Rice, W. N., and Gregory, H. E., Manual of the geology of Connecticut: Connecticut Geol. and Nat. Hist. Survey Bull. 6, p. 141, 1906.

that is often applied to it. It has a moderate porosity and is able to absorb and transmit considerable water. The water is most abundant in the zone immediately overlying the bedrock and in a few widely scattered lenses of partly washed and roughly stratified material within the till. Wells dug into the till to a depth below the lowest level reached by the top of the saturated zone in times of drought will procure satisfactory supplies of water. Measurements were made of 31 such wells in Marlboro in September, 1916. Of these wells 19 were said to be nonfailing and 7 were said to fail; the reliability of the remaining 5 wells was not ascertained. The following table summarizes the data collected concerning the depths of these 31 wells:

Summary of wells dug in till in Marlboro.

	Total depth.	Depth to water.	Depth of water in well.
	Feet.	*Feet.*	*Feet.*
Maximum	29.2	21.5	16.8
Minimum	8.7	4.1	1.6
Average	15.7	10.7	5.0

QUALITY OF GROUND WATER.

The accompanying table gives the results of two analyses and three assays of samples of ground water collected in the town of Marlboro. The waters are low in mineral content, except Nos. 19 and 26, which are moderately mineralized. Nos. 12 and 27 are very soft, No. 23 is soft, and Nos. 19 and 26 are comparatively hard. All are acceptable for domestic use in so far as this may be determined by a chemical investigation of their mineral content. Nos. 12 and 27 are suitable for boiler use, but the other three are rated fair for boiler use because they contain considerable amounts of scale-forming ingredients. No. 19, moreover, is liable to cause a little trouble by foaming. Nos. 12 and 27 are sodium-carbonate waters; Nos. 23 and 26 are calcium-carbonate in type; and No. 19 is classed as a sodium-chloride water.

Chemical composition and classification of ground waters in Marlboro.[a]

[Parts per million. Collected Dec. 5, 1916; analyzed by Alfred A. Chambers and C. H. Kidwell. Numbers of analyses and assays correspond to those used on Pl. VI.]

	Analyses.[b]		Assays.[c]		
	12	27	19	23	26
Silica (SiO_2)	19	22			
Iron (Fe)	.42	.10	0.17	0.16	0.67
Calcium (Ca)	4.9	3.6			
Magnesium (Mg)	2.5	1.6			
Sodium and potassium (Na+K)[d]	13	9.8	72	5	Trace
Carbonate radicle (CO_3)	.0	.0	.0	.0	.0
Bicarbonate radicle (HCO_3)	27	29	79	66	91
Sulphate radicle (SO_4)	19	4.8	43	8.0	18
Chloride radicle (Cl)	4.8	5.2	133	18	16
Nitrate radicle (NO_3)	3.1	.94			
Total dissolved solids at 180° C	78	60	[d]370	[d]120	[d]160
Total hardness as $CaCO_3$	[d]22	[d]16	155	78	117
Scale-forming constituents[d]	38	35	180	100	140
Foaming constituents[d]	35	26	190	10	([e])
Chemical character	Na-CO_3	Na-CO_3	Na-Cl	Ca-CO_3	Ca-CO_3
Probability of corrosion[f]	(?)	N	(?)	(?)	(?)
Quality for boiler use	Good.	Good.	Fair.	Fair.	Fair.
Quality for domestic use	Good.	Good	Good.	Good.	Good.

[a] For location and other descriptive information see p. 166.
[b] For methods used in analyses and accuracy of results see pp. 52-60.
[c] Approximations; for methods used in assays and reliability of results see pp. 52-60.
[d] Computed.
[e] Less than 10 parts per million.
[f] Based on computed quantity; (?)=corrosion uncertain, N=noncorrosive.

RECORDS OF WELLS AND SPRINGS.

The only spring visited in Marlboro (No. 9, Pl. VI) is so situated on a slope that the water is brought to the surface by a ledge of bedrock. It yields about half a gallon a minute.

Dug wells in Marlboro.

No. on Pl. VI.	Owner.	Topographic position.	Elevation above sea level.	Total depth.	Depth to water.	Depth of water in well.	Rig.	Remarks.
			Feet.	*Feet.*	*Feet.*	*Feet.*		
1	....	Slope...	670	16.7	5.2	11.5	Sweep rig.......	Abandoned.
2	....	...do....	570	27.1	10.3	16.8	One-bucket rig..	Nonfailing.
3	....	Plain...	420	16.1	11.2	4.9	Sweep rig.......	Do.
4	Louis Krumholtz....	Slope...	410	16.5	14.3	2.2	Chain pump....	Do.
5	....	Ridge...	480	20.4	13.8	6.6	Windlass rig....	Fails.
6	....	Slope...	610	21.6	16.4	5.2	Sweep rig.......	Do.
7	....	...do....	410	18.4	15.9	2.5	Windlass rig....	
8	....	Low hill	410	18.4	15.5	2.9	.....do..........	
10	....	Slope....	510	17.4	13.1	4.3	.....do..........	Nonfailing.
11	....	Swale...	590	8.7	2.8	5.9	No rig..........	
12	H. G. Austin........	Slope...	410	17.3	15.1	2.2	Chain pump....	Nonfailing. Water from till. For analysis see p. 165
13	....	...do....	430	15.1	9.9	5.2	Windlass rig....	Fails. Rock bottom.
14	Herman Dermler....	Ridge...	485	15.2	12.0	3.2	One-bucket rig..	Do.
15	....	Slope....	440	10.3	8.7	1.6	Windlass rig....	Fails.
16	....	...do....	495	10.6	7.0	3.6	Chain pump....	Do.
17	R. Hurowitz.........	Plateau.	550	13.0	9.7	3.3	Windlass rig....	Nonfailing.
18	....	Slope....	450	14.1	11.3	2.8	House pump....	Do.
19	L. L. Buell..........	...do....	665	15.8	6.4	9.4	Chain pump......	Nonfailing. In rock 11 feet. Water from gneiss. For assay see p. 165.
20	Robbins.............	Plateau.	650	12.2	5.3	6.9	House pump....	Nonfailing.
21	....	Slope...	600	12.8	9.0	3.8	Windlass rig....	Fails.
22	E. E. Hall..........	...do....	550	22.1	16.3	5.8	Windlass on counter balance rig.	Nonfailing.
23	Methodist Church...	Plateau.	565	12.1	6.4	5.7	Windlass rig....	Fails. Water from till. For assay see p. 165.
24	....	Slope....	550	13.8	9.3	4.5	.....do..........	
25	....	...do....	410	14.6	9.0	5.6	Chain pump....	Nonfailing.
26	Mrs. A. R. Gray	...do....	500	15.3	12.5	2.8	Air-pressure system.	Nonfailing. Water from till. For assay see p. 165.
27	B. S. Lord..........	...do....	520	10.7	4.1	6.6	Gravity system.	Nonfailing. Water from till. For analysis see p. 165.
28	....	...do....	420	9.4	6.5	2.9	Two-bucket rig..	Nonfailing.
29	....	...do....	400	29.2	21.5	7.7	Windlass rig....	Do.
30	....	...do....	390	10.4	6.4	4.0	No rig...........	Do.
31	....	...do....	380	17.6	12.6	5.0	Chain pump....	Do.
32	....	...do....	400	14.0	11.1	2.9	Windlass rig and house pump.	Do.

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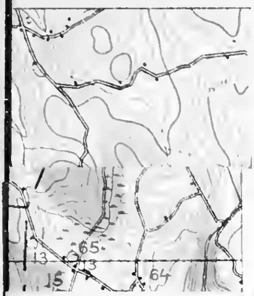
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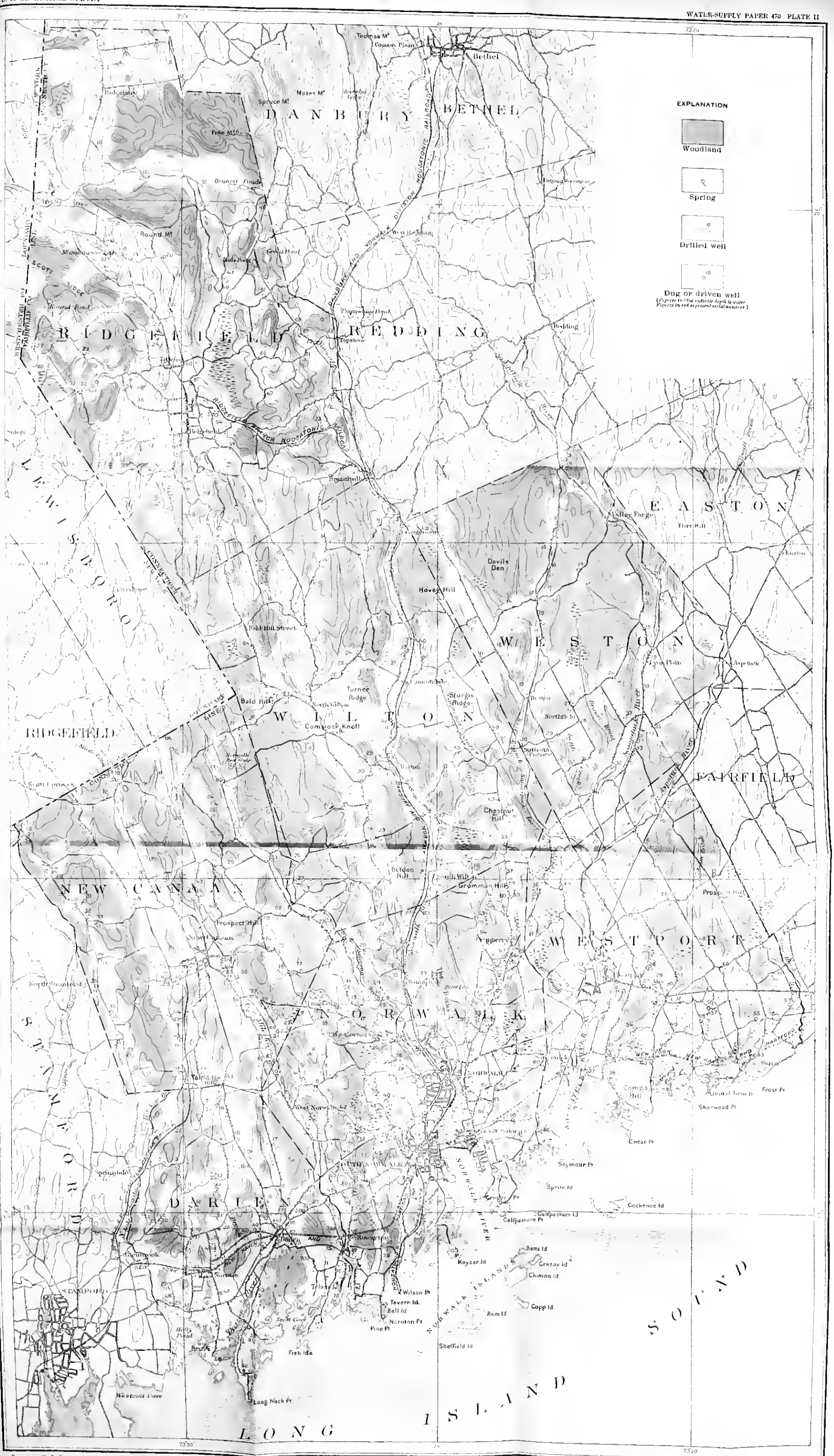

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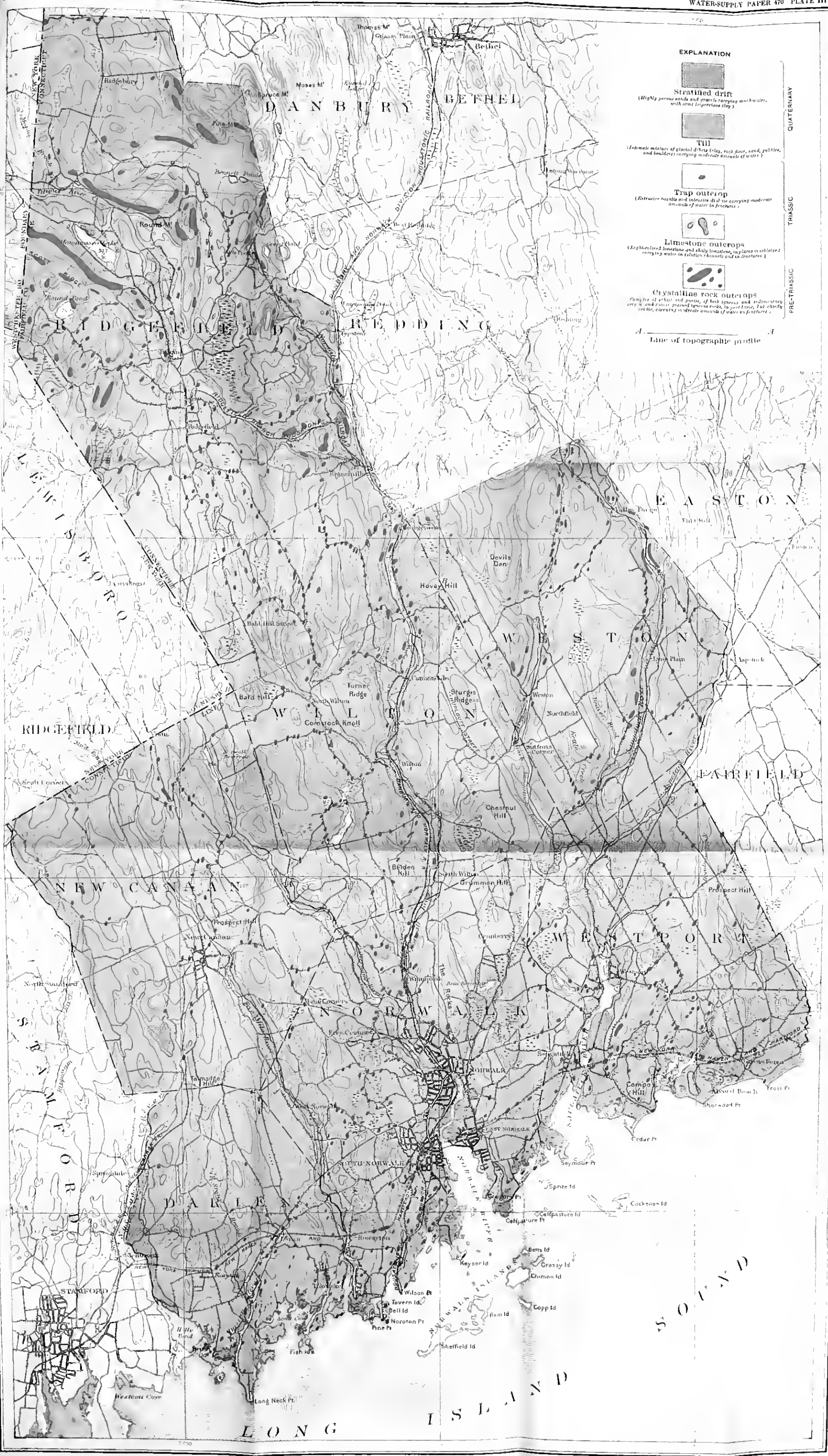
Locations of woodlands, springs, and wells by H. S. Palmer

TOPOGRAPHIC MAP OF THE NORWALK AREA, CONNECTICUT

Showing distribution of woodland and location of wells and springs cited

Contour interval 20 feet

1920



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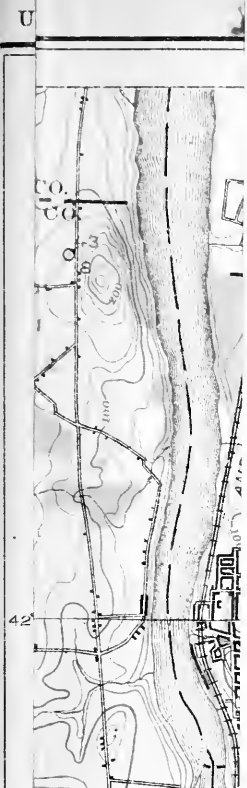
MAP OF SURFACE DEPOSITS OF THE NORWALK AREA, CONNECTICUT

Scale $\frac{1}{62500}$

Contour interval 20 feet

Datum is mean sea level

1920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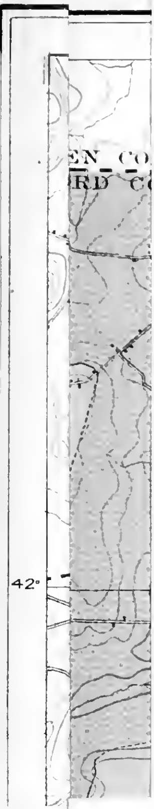

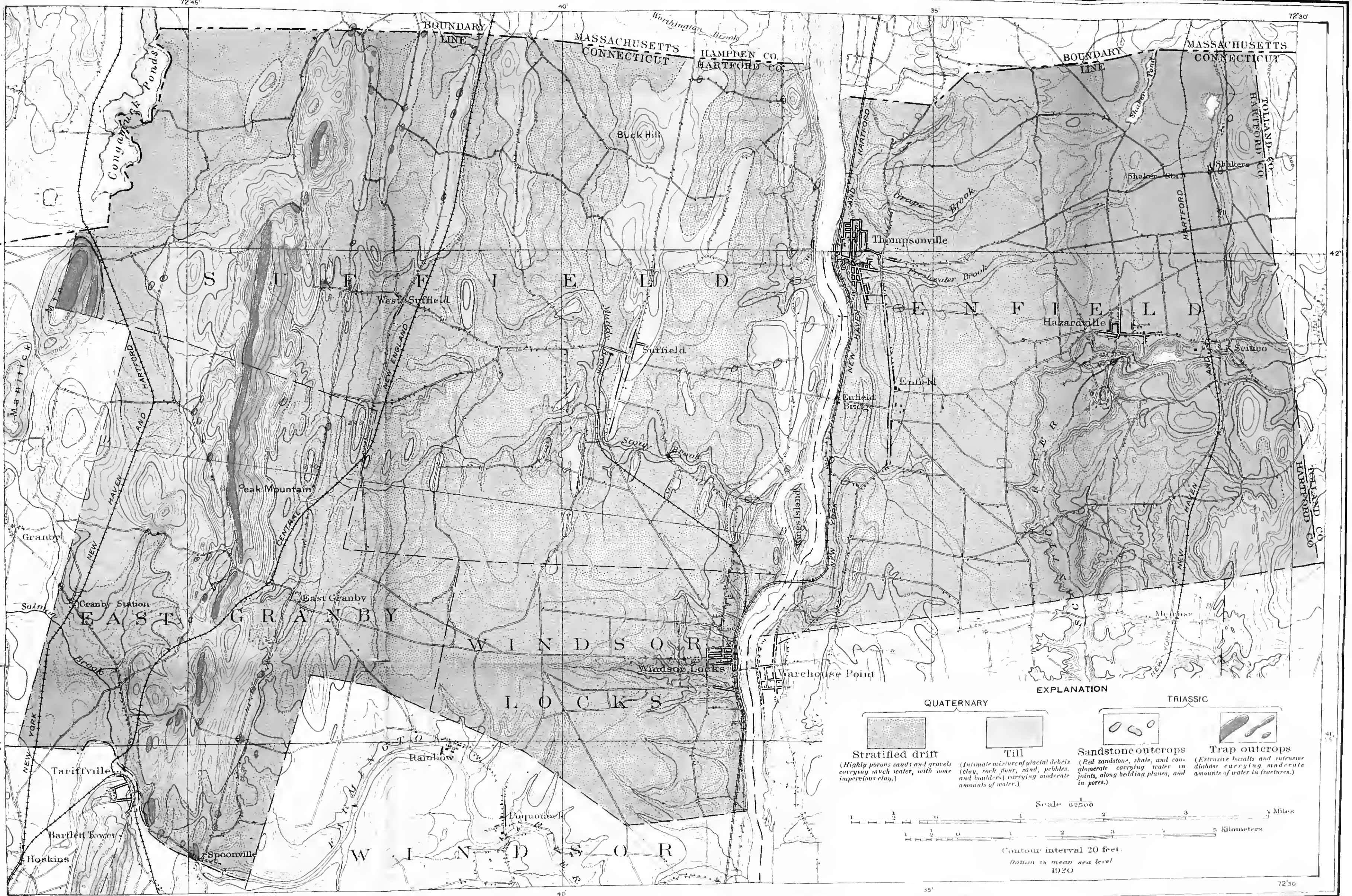

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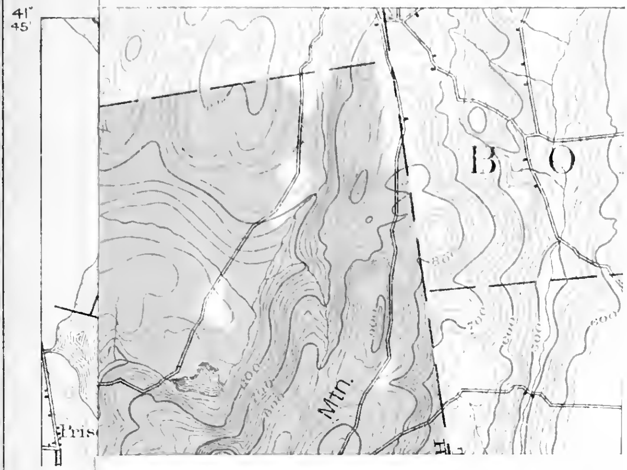
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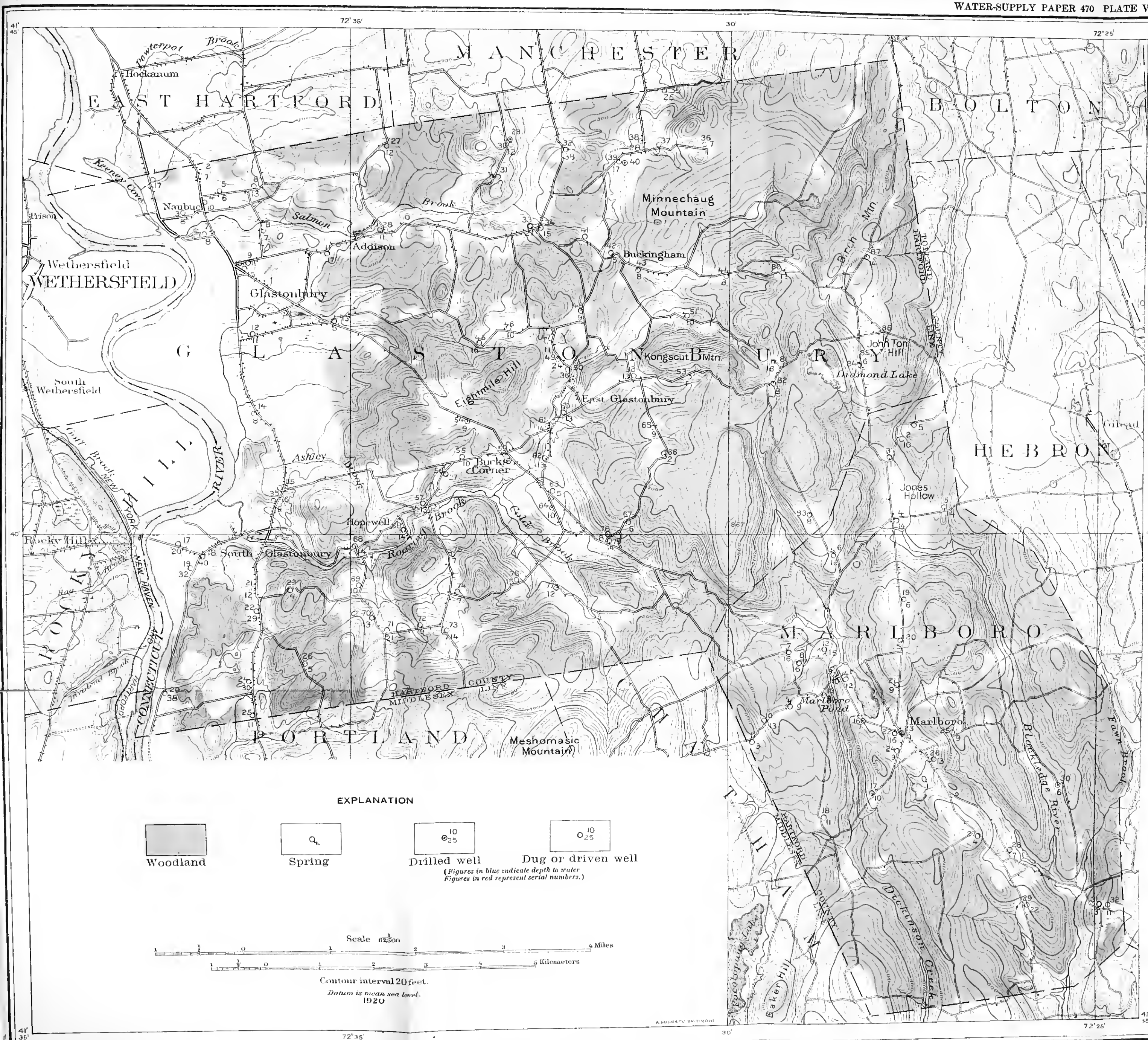

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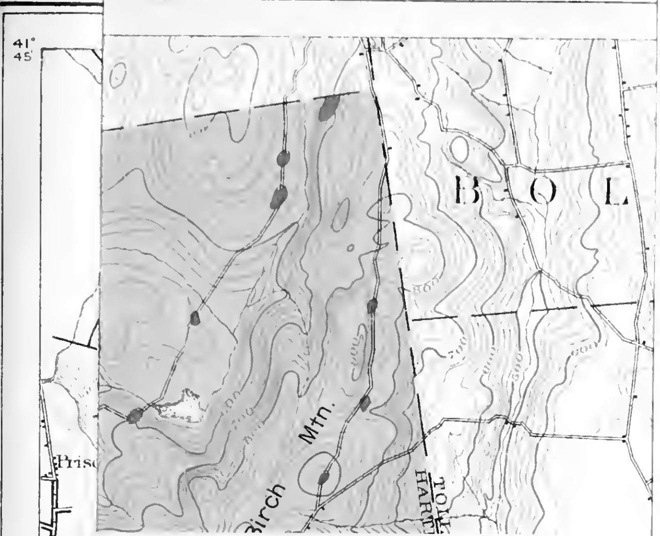
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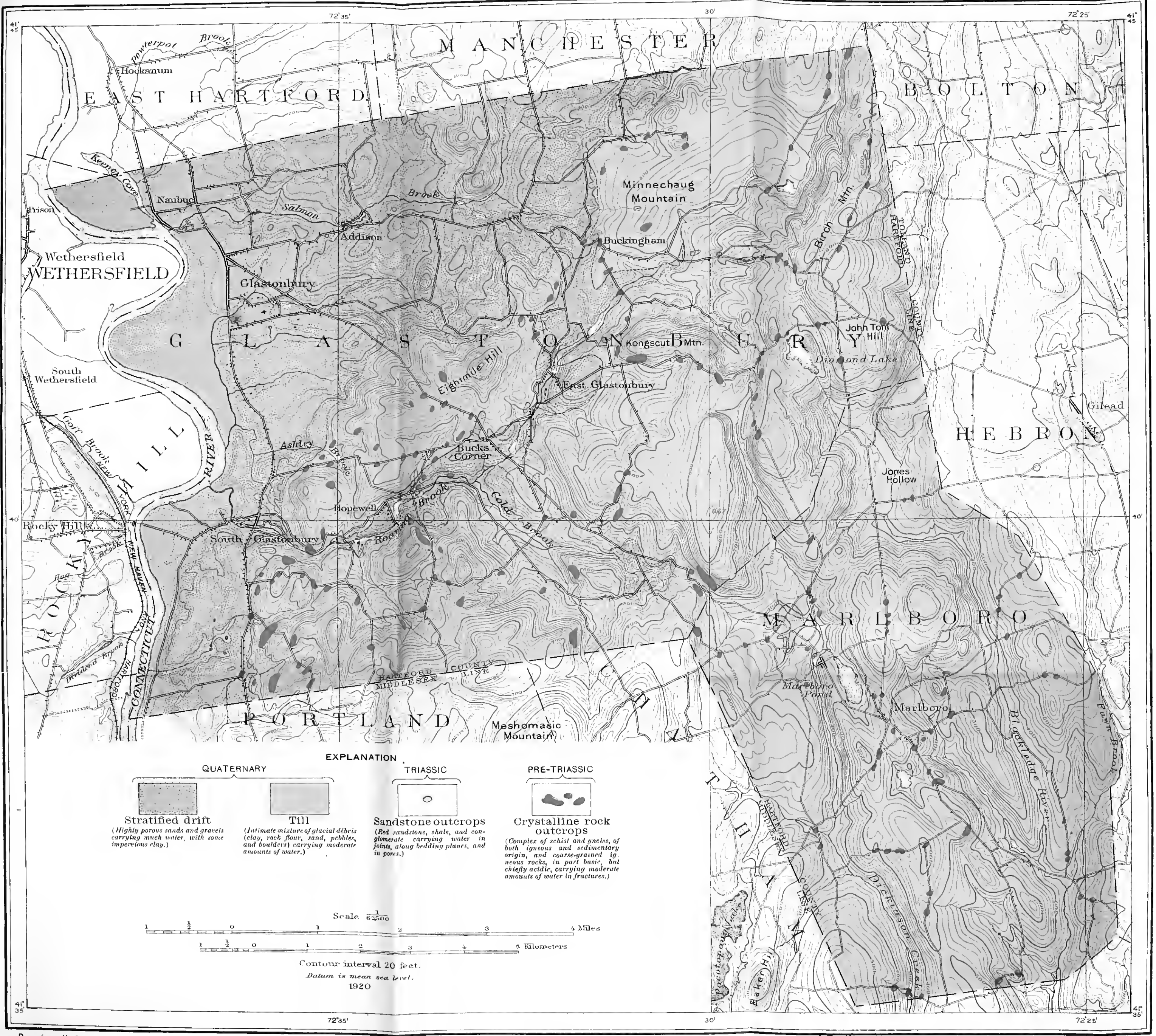

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